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# CLOSER TIES WITH IUFRO CAN ENHANCE FOREST OPERATIONS RESEARCH IN EASTERN CANADA

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FDC: 972.12 IUFRO: 30: (71)

These comments have been prepared for presentation to the International Union of Forestry Research Organizations (IUFRO), Forest Operations Division (Div. 3), at its plenary session, 19th World Congress to be held in Canada during August, 1990.

## OBJECTIVE

As I am a Canadian attending IUFRO's first World Congress ever held in Canada, and being a deputy coordinator of Div. 3 nearing completion of my tenure in that responsibility, I have been given this opportunity to outline my thoughts relating to the objective of finding better ways to enhance forest operations research and development in the eastern Canadian region. In the early 1960's, development activity designed to produce improved forest operations systems for the region was encouraging following several significant successes but, unfortunately, the early momentum did not continue at an acceptable pace to meet expectations. Why this occurred is the problem at hand.

In my opinion, the region's basic problem is rooted in too much dependance upon innovative machine development (e.g. replacing woods horses with choker wheel skidders) rather than seeking effective solutions to scientifically analysed systems' weaknesses. If this is indeed so, then it would seem that systems designers should turn to more effective scientific systems analysis without reducing efforts designed to develop innovative new machine, or mechanized/manual, systems. I believe that closer ties with IUFRO, Div. 3 could assist eastern Canadian forest operations systems designers in their objective of enhancing both research and development. However, in most Canadian forest operations, research is the weaker element and therefore requires more attention than does the development element.

## IUFRO AS AN INTERNATIONAL RESEARCH ORGANIZATION

IUFRO, Div. 3 did not play a significant part in eastern Canada's forest operations development successes of the early 1960's. Activity was centered in Europe because research leadership and scientific endeavour was undoubtedly concentrated there. My own involvement with IUFRO, Div. 3 (Section 32 at that time) did not begin until 1964 when I was requested to lead a study tour forming part of a major Div. 3 meeting being held for the first time in eastern Canada. Since that time Div. 3 has had major meetings in eastern Canada at ten-year intervals (i.e. 1974 and 1984). The 1984 meeting, hosted by the University of New Brunswick, was particularly useful as it was held in conjunction with the Council On Forest Engineering annual meeting hosted by the University of Maine.

IUFRO's desire to become more international in scope was strengthened in 1971 when the 15th World Congress took place in The United States of America; outside Europe for the first time. This trend continues as the 17th World Congress was hosted by Japan, and the 19th is meeting here in Canada.

The organizational structure of IUFRO has proven itself to be effective in the full range of forestry related research, yet it still allows a high level of flexibility for individual researchers. It is my belief that IUFRO is a uniquely effective forestry research organization devoted to maintaining a forum where forestry related scientists can interchange and discuss their research on an international basis. The degree of individual involvement will usually determine the values gained. Although conditions and objectives often vary from one geographic region to others, problems encountered and their solutions may be remarkably similar. As circumstances change over time (e.g. quantity and quality of the forest resource), it becomes essential to understand the successes and failures of those scientists who have dealt with similar challenges previously. IUFRO scientists can have a role to play in eastern Canadian forest operations research and there are mutual benefits to be gained from development achievements in that region (e.g. P3.05-00, Riga, Sept., 1989 meeting - Harvesting and utilization of tree foliage).

## A SUGGESTION FOR DIV. 3 CONSIDERATION

Based upon the assumptions that forest operations development in eastern Canada is of professional interest to many IUFRO, Div. 3 members, and that many of eastern Canada's current and near-future requirements relate, at least in part, to research projects under study in other world regions; it is my contention that both IUFRO, Div. 3 members and eastern Canadian forest operations systems developers can enhance their efforts by providing cooperative research opportunities through closer ties with one another. For many this of course is not a new concept. It is suggested, however, that the objectives outlined previously may be met initially by taking advantage of the momentum provided by this World Congress, hosted by Canada, to improve upon past activity. Of major importance is the involvement of more Canadians in IUFRO, Div. 3, and a better understanding by forest operations systems developers of the potential advantages available from closer ties with IUFRO.

As an example of one specific course of action that may be considered, I offer the following scenario:

1. IUFRO, Div. 3 to hold a joint meeting in cooperation with an eastern Canadian forest operations systems development group during 1994 (i.e. continuing the established ten-year tradition);

2. the meeting theme would be broad in scope and may deal with <<forest uses management>>, an emerging topic of considerable interest in Canada and a topic of long-term concern for many forest operations researchers;

3. open technical presentations and a business meeting(s) would be the responsibility of Div. 3 members;

4. the Canadian development group would coordinate and host an extensive study tour for the joint meeting attendees.

In summary, this suggestion proposes bringing together objectives first undertaken in 1964, combined with progress achieved by the 1984 meeting, to promote interchange between developers and researchers leading to enhanced forest operations systems.

# FOREST RESEARCH
# IN ECOLOGICAL ECONOMIC PERSPECTIVE

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**This paper highlights some of the topics which will be raised at the Sub Plenary Session on "Forests for industrial requirements including energy - assessment, inventory and supply".**

In biological science a new research approach heralded by Howard T. Odum (1982) during the last decades greatly enhanced the understanding and knowledge about the mechanisms that determine the development and structure of live systems and organisms. This approach is based on the laws of energy, named Systems Ecology, now employed at most biological research institutes all over the world. It regards biological systems as a unidirectional flow of energy and matter with feedback loops that reinforce the interactions of the system. Surviving patterns are those that get most energy and use energy most effectively, develop more power inflow and use it best to meet the needs of survival according to the Maximum Power Principle, originally formulated by Lotka, already in the 1920's and slightly modified by Odum (Odum & Odum, 1976, p40).

The principles of Systems Ecology and the laws of energy later on were applied by many researchers (Costanza, 1984, Hall et al, 1986, Cleveland, 1987 and others) also for analyses of human systems and economies and Odum in the 1980's presented the Unifying Systems Theory embracing also earth systems and astronomic systems (Odum, 1987, p26, 1988).

In the science of economics there existed since long a school, recently reviewed by Martinez Alier (1987), critical to some of the fundamental principles of the well established and dominating neoclassical economic theories. This school of thought recognizes as opposed to neoclassical economics that economic activity is constrained by the finiteness of natural resources, in particular energy. It is critical to methods for integrational allocation of resources and argues that substitution of scarce matters is unrealistic and that non-market values are disregarded etc. The criticism has now been revived by several researchers, as it seems greatly influenced by the principles of Systems Ecology and also of Energy Analysis, developing into an infant science (perhaps only a perspective), Ecological Economics, for which also the laws of energy form the base.

Economic theory was early applied in forest management and policy, e g Faustmann's formulae, the basic model in investment theory developing into the school of the soil rent theory in forest economics. This theory was contradicted by the forest rent theory and this contradiction has still not been resolved. Forest legislation, policy and practice have in fact been imprinted more by common sense, values of forest owners and the public than by economic theory.

Forestry is basically concerned with the transformation of solar energy into goods and services demanded by man. The forest also play an important role in maintaining a sound environment as a recipient of and filter for harmful emissions, emerging from an extravagant use of energy. Analyses of forestry in an energy perspective is therefore always meaningful and enhances our knowledge of the functioning of forest ecosystems and impact of human manipulation. In addition, Ecological Economics attempts to synthesize such energy analyses into values - into money and including also intangible values some of which are regarded as externalities in economic theories. It attempts to fill a vacuum between ecology and standard economics and provide results of better utility for decision making, especially long term ones, than old disciplines can. Its focus is on the intersections between natural and social sciences.

Forestry would be an especially apt target for developing and demonstrating the operation value of Ecological Economics. To realize this will require that energy is added in all traditional sub-disciplines in forest science as a parameter of inputs and outputs, complimentary to the traditionally used scales.

Despite unpresedental growth in the west, there are concomitant signs of irreversible environmental and social degradation. As the world surely is entering an area with declining net energy, the role of the forests is bound to increase. Forest research must adjust to these changes so it better can analyze the constantly evolving processes in interactions between the Natural World and human economies and also be able to describe these in terms and language, meaningful and understandable for the public and the decision makers. Ecological economics holds promise to meet these needs.

The presentation at the IUFRO Congress will outline in more detail the state of the art of Ecological Economics and suggest strategies and action plans to integrate Ecological Economic perspectives into forestry.

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# OR in Forest Operations:

## New Environments, Tools and Approaches

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## SUMMARY

Forest operation managers are encountering a remarkably changed decision environment. Evolution and progress in the areas of organizational structures, problem complexities, responsibilities, data availability and information technology ensure that such changes will continue. There is evidence that the approaches taken in the past to introduce operations research into the managerial decision making culture have met with limited success. New approaches, based upon what has been learned from past mistakes and what can be expected from the future decision environment, must concentrate more on improving the entire decision process than on model development.

**Keywords:** Forest Operation Management, Decision Environment, Operations Research Methodologies

## INTRODUCTION

As a reader of science fiction, I am often made aware of the weaknesses and strengths of the genre and of the pitfalls that its writers must beware. In its lowest form, science fiction stories are melodramatic fantasies in which lazy writers manipulate the plot by using "magic" and express points of view without giving us the background material we need to understand the characters' motivation. Technological marvels are used to disguise the fact that the story has nothing worthwhile to say about the human condition.

Sometimes, however, science fiction works the way I believe it should: it forces us to question basic beliefs and tenets that we may think are basic and inviolable. The ideas presented may transcend time and place, but they are taken out of the present context so that we, the readers, feel unfettered by contemporary physical, cultural, societal or political barriers. In other words, the new context is there for our sakes, not to make life easier for the author.

What does all this have to do with the future of operations research (OR) in forest operations? In my opinion, the function of OR is to help managers better understand some part of their working lives. Its main purpose is not to provide precise solutions to the larger questions, but rather to help managers be more effective at finding the answers for themselves. As with science fiction, OR should focus more on the formulation of questions rather than on providing answers. Gass (1989) believes that the role of models is "not so much to explain and predict....as to polarize thinking and to pose sharp questions". Even if we (like good science fiction writers) must employ artificial constructs to accomplish this, ultimately the benefit to the users will only come when they can take some element of our fantasy and apply it to their own circumstances.

The focus of this paper is on strategies that I propose applied OR researchers and developers should adopt which may be more successful at contributing to forest operation decision making in the future. In order to accomplish this I will first describe current and likely future managerial decision environments. Then I will explain why previous model design, development and implementation approaches may not have been very successful in the past. Finally I will propose elements of an approach that should result in a greater degree of acceptance of OR techniques in day-to-day forest operation management.

## DECISION ENVIRONMENTS

### Current Status

According to Drucker (1988), organizations are becoming more information based, flatter, more task oriented, driven more by professional specialists, and more dependent on clearly focused missions. Now that may be true of organizations in general, but are there indications that this is also the case in forest operations? In this section of the paper, the current status of the following factors influencing decision environments will be considered: organizational structures, problem complexity, authority and discretion, data availability and information technology.

#### Organizational Structure:

It appears that forest product companies are developing flatter and leaner organizational structures. Organizational shake-ups continue to occur and retiring managers are often not being replaced. However, contrary to Drucker's projections, while the scope of line managers' jobs are broadening, the ranks of staff specialists that would normally support the management function in such circumstances are not yet being increased. Whether this is to be a long-lived phenomenon is difficult to envisage, since it is obvious that some companies have forced their management structures to become much flatter and leaner without giving them the support such a structure demands.

Problem complexity:

It is quite certain that the problem environments most managements find themselves in have not become any simpler. Operational, regulatory, environmental and societal objectives and constraints are becoming more complex, volatile and sensitive. Unfortunately, as stated above, managers are required to solve increasingly complicated problems with little help from professional specialists. They are now required to produce plans that place more emphasis on qualitative criteria. For instance, some managers must now evaluate the efficacy and efficiency of plans under the constraints of sustainable development. In such situations the lack of appropriate decision tools and evaluation criteria may tempt managers to use naive rules and large factors of safety in their decision making or they simply stop making effective decisions altogether.

Authority and discretion:

Flatter organizations usually necessitate more decentralized decision making, with managers having more authority and taking on more responsibility. Complex problem environments usually mean that solution paths are not clear and managers must be allowed to use their discretion in identifying and evaluating alternatives. Unfortunately, it seems that many of these leaner organizations have not yet decentralized their decision making. This may be due, in large part, to the fact that the coordination and integration of decisions becomes more important in complex situations and the technology for such integration has not yet been adopted. This means, of course, that top management is buried under detail, making poor decisions or not making decisions at all, while lower managers are not able to make decisions that are obvious to them. Again, in some cases the problem is "solved" by narrowing the range of possible solutions that are considered. It is uncertain whether companies will wish to continue taking such risks.

Data availability:

Organizations are almost invariably becoming more data-rich. As data gathering and storage become increasingly automated, the cost of the acquiring data continues to fall. In most companies once data is gathered and stored, it is readily available (technically, at least) to all parts of the organization that have need of it. It is also true, however, that managers often do not use all the data available to them, even when it might be used to improve the quality of their decisions. I have encountered some managers who say that they are actually considering spending less time and money gathering and maintaining forest resource data. They feel that the information it provides is not worth the effort with respect to the decisions and issues that really affect their operations' performances.

Information Technology:

There are forest product companies throughout the world that have been very progressive with respect to the acquisition and application of innovative information technology. Such organizations have often been far ahead of the mainstream of their respective societies in the quantity and calibre of implementations. However, such organizations are not in the majority, and even in their cases innovation usually centres on systems for forest resource management and corporate financial control, not forest operations managers' decision making. It is unfortunately true that technically feasible data-retrieval capability has too rarely been turned into informational reality for forest operation managers. One reason for this is that even with the new development tools available, applications software development has lagged far behind managements' needs. In the case cited above concerning a possible reduction in the quantity and quality of forest resource data, managers agreed that they would probably change their minds if better resource data could be combined with better productivity data to provide real information. These are cases where missing certain types of data or the inability to process data that already exists critically reduces the value of the data. Forest product companies have not learned enough about turning data into useful information.

Although the current decision environment of forest operation managers is lacking in many respects, there are indications that companies are moving to correct many of these problems. For example, I have worked with an Eastern Canadian forest products company whose decision environment was, until a few years ago, probably worse than even the dismal average for the industry. However, after a major restructuring that saw the introduction of a flatter, leaner organization in a more complex operational and regulatory environment, the company recognized that its managers needed to have the tools to help them in their revamped jobs. Despite initial resistance from some, they have adopted many computer-based decision making tools. Even the recalcitrant ones have recently admitted that they couldn't return to the old ways. Most recently they have hired a forest operation information systems expert to help them chart the future directions these systems should take. This new person reports directly to the Woodlands Manager who recognizes the necessity of better information in the new circumstances. The lesson to be learned here is that even less innovative organizations can be made to recognize that, to a great extent, their survival depends on how successful they are at improving the managers' decision environment.

## The New Environment

I believe that this sort of approach will be taken in most companies in the next decade. Management structures may become even flatter despite the fact that the problem environment will become more complex and difficult to solve. However, companies will overcome these constraints by improving managers' abilities to access expert knowledge by hiring more specialists,working with consultants and/or using information technology to access "knowledge bases". In fact, Schein (1989) goes so far as to say that managerial hierarchies, as we know them, may play a much smaller role in the future and may even cease to exist in some organizations. He suggests that increased technological complexity and advances in information technology will lead to the development of very different management approaches. Some suggest that, since a wide range of expertise will be required, a heterarchial (as opposed to hierarchial) structure may make more sense (Hedberg et al, 1976) and that the evolving workplace will feature "controlled diversity" (Schein, 1986). Even if the hierarchial approach is generally maintained, a good case can be made for more of a team approach in the future. In such a team, the operational manager would implement plans that a group of experts and managers (including himself) have formulated, perhaps after several rounds of analysis and negotiation. This would tend to satisfy the need for a wide variety of expert knowledge in the solution of complex problems. Existing and new information and communication technology which facilitates coordinated and integrated group decision making would allow this to occur without the necessity of face-to-face meetings. The operation manager could access the appropriate individuals in other departments, other locations and sometimes even other organizations.

Although application software development tends to lag far behind the hardware that is available, new languages which facilitate the development of decision support systems (DSSs) are increasingly finding their way into the marketplace. True fourth-generation languages, expert system shells, powerful development tools and data-transfer (or even data-bonding) tools have sharply reduced the time and effort required to design, develop and implement integrative management information systems and DSSs. "Forgiving" systems designed for use by ordinary managers are already beginning to appear. It is likely that in the future systems may be developed using adaptive, learning systems which adjust information presentation schemes, data structures and program code to suit varying problem types, data availability (quantity and quality) and individual decision making styles. Proper system development will really begin when these tools can be generally designed, developed and maintained without the intervention of (human) system analysts. Managers will know WHAT they want done, artificial intelligence techniques will be used to determine HOW it should be done.

I have gathered considerable anecdotal evidence which infers that, as information technology improves, managers will tend to gather more and better data. In some cases the implementation of better cost analysis systems fuelled the demand for more equitable contract schemes, and this resulted in a marked increase in the use of time studies, forest inventory analysis and improved production reporting. One company I have worked with has instituted a time and cost reporting and analysis scheme for the contractors it employs. This, along with other cost analysis and reporting software it has implemented, will be used as the basis of contract negotiations where all parties will have a better understanding of true costs and potential areas for increased efficiency. In the future the problem will rarely be one of data availability, but rather of ensuring that the managerial environment is conducive to transforming data into decision relevant information.

## OR APPROACHES

### Current OR Methodology

Harrison and de Kluyver (1984) point out that "there are a number of areas in the forest products industry still relatively untouched by MS/OR." It is likely that the planning and control of forest operations is one such area. It is true that productivity and cost models are used for equipment choice and system design in capital acquisition and strategic decision-making.

As well, many simulation models and other tools for forest operation analysis and planning have been developed by university, government and industrial researchers. However, when a survey of actual managerial planning processes in Canadian forest products companies was undertaken in the early eighties (Prasad, 1985), it showed that few such models or techniques were used by forest operation managers on a daily basis. It seems that though managers may express interest in OR techniques, they rarely get around to actually using them.

It may be tempting to blame this on the backwardness of forest industry personnel. However, the literature that exists on the broader issue of decision-making reveals that the tendency not to apply rationally-based models is a pervasive trait of management (Kunreuther and Schoemaker, 1982). Besides ignoring "logical" models, managers often seem to make "irrational" decisions (see Connolly, 1977 and Simon, 1979). There is, in fact, empirical evidence that human decision processes themselves may not always comply with rational models (Schweder, 1977). It might be concluded, then, that OR researchers and practitioners have been wise to concentrate their efforts on developing logical, precise and sophisticated models. After all, if "humans are such poor and unsystematic decision makers" as research indicates (Kunreuther and Schoemaker, 1982), then managers would benefit from the use of logical decision models that identify and prescribe "optimal solutions".

However, even if this were true, OR people must come to grips with the possibility that the current approaches to model development are deficient since the solutions these models offer often seem unimplementable. March (1978) suggests that optimising models are based upon "macroadaptive rationality" which requires that a situation be stable enough for actual and optimal behaviour to coincide. Since (as noted earlier) managerial decision making often exists in a complex and volatile environments, "microadaptive rationality" may be a more productive approach (Connolly, 1982). Such a microadaptive process would be one where managers analyze and plan part of the entire project, evaluate the results with respect to standards (of cost or production, perhaps) and overall objectives, and then continue the planning process. Sensitivity analysis could be used to guide the evolving plan toward the final goals. Since some researchers (as reported by March and Shapira, 1982) have found that organizations often have poorly articulated goals and use preference rules which favour acceptable (not optimal) performance, microadaptive strategies may be more appropriate.

Mintzberg (1982) states that research into complex decision situations has shown that managerial decision making based upon limited information, experience and intuition may yield better results than purely rational models. As well, although some managerial decision processes do not follow the rational model, they are not necessarily "irrational". Rather, they may act at such deep levels of human consciousness that they are incapable of being described through current methods of decision analysis. It may well be that "It is we theorists who are poor decision makers ... so intent are we on promoting our own perspective that we blind ourselves to reality" (Mintzberg, 1982).

Modelling approaches that ignore the complex managerial decision environment (and the methods managers have adopted to cope with it) could well be the reason for the limited success of OR. Managers may reject optimization models because they are overly simplified representations of a complex problem environment. It is managers (not modellers) who must justify, implement and control such solutions. This may be impossible if the solution-generation process is so complex as to be opaque to managers. Managers may be unable to detect when solutions are invalid or circumstances have changed to such an extent that the model should be re-run with new data or structurally modified.

These experiences illustrate some of the problems in system and model development that traditional OR technology has not solved. Approaches that stress "rational" models prescribed by OR experts appeared to fail too often to be labelled abberations. The results of decision theory research indicate that, especially where complex problems involving conflicting goals and unstructured decision environments are concerned, these model design and development methods are not compatible with the ways people actually make decisions (Einhorn and Hogarth, 1982).

## Approaches For The New Age

If my predictions concerning the decision environments of forest operation managers are generally accurate, there are several implications for OR. First there is good news regarding data, information systems and managers' attitudes. We should be able to depend upon the availability of a great deal more good data in forestry organizations. The system development tools available to us will be far superior to what we have had in the past. The managers who work with us will have a great deal more appreciation of the value of good data and information, and will be much more accustomed to working with information technology.

Unfortunately, however, some impediments to OR system development and implementation will increase and new problems are on the horizon. Managers will be responsible for a wider range of activities and/or will be working in a relatively autonomous team and so won't be able to depend on a hierarchial structure to facilitate the coordination and integration of activities. More than ever, managers will have to deal with the fact that important objectives and constraints may be non-quantifiable and that the decisions they make may have to be "negotiated" with other significant decision makers. The problems that managers must solve will be even more complex and volatile, and will require the skills and knowledge of greater ranges of expertise. Overall then, there is little reason to believe that it would be right to continue attempting to apply approaches that have had such limited success in the past. Attempting to develop models that supply "the right answer" to the "ignorant user" will continue to be useful in only the most structured (and generally trivial) situations. Instead, if OR technology is to be truly helpful in the mainstream of forest operation management decision making, it must be made applicable to the majority of decision situations: all those messy ones where a single correct solution does not exist. In my opinion, this means that we should concentrate more on developing aids for the decision making process and less on modelling. The following, then, are the elements of an approach that I believe will lead to more successful OR implementations in such an environment.

(1) The first thing I would propose is to go back to basics: problem-solving. In several articles I have seen in the Institute of Management Science journal Interfaces in recent months, some of the older hands in the OR game and others recalling the history of OR have insisted that the focus of the "venerable OR pioneers of the past" was on problem-solving, not model-building (for example see Miser, 1989). There are too many modellers who have become so enamoured by some small set of specific modelling techniques that their first reaction when presented with a problem is to start pulling techniques out of their model tool kit that "suit the problem type". As one such modeller told me, "I've developed the model, if they won't or can't implement it it's not my problem". I would suggest to him that he is taking a narrow view of his role if he thinks that he has done his part by providing an unimplementable solution.

(2) The second element follows from the first. Many of the most important and complex decisions (ie. the ones managers need help with) are ones that involve multiple objectives (some of which may be non-quantifiable) and multiple decision makers. In such cases, the need to integrate the use of an eclectic collection of models by a group of people with different objectives will mean that the OR system designer will be required to spend much more time analyzing and designing overall decision making processes. For instance, if the situation calls for negotiations between sets of decision makers, then it is the responsibility of the OR developer to ensure that the system design takes this into account. It is likely that the developer will be required to be more eclectic in his application of techniques. LP, DP, simulation models, expert systems and stochastic techniques may be tied together into a large system that also specifies how the various decision makers will negotiate a solution.

(3) In order to satisfy the need for more holistic systems that help generate solutions to multi-criteria, multiple decision maker problems, OR developers must ensure that the systems they design are integrative and coordinative. Great advantage can be achieved by spending more time on linking models (sub-systems) to others in such a way that the partial solutions are compatible with each other and the various decision makers understand and accept the overall solution (Benjamin and Scott Morton, 1988). Since data-sharing and data-bonding are likely to be used, a

major responsibility of the OR developer will be to ensure the integrity of the entire system.

(4) OR developers will have to face the fact that, in many complex situations, optimal solutions may not exist or, if they do, managers may have no idea how to implement them. In those cases, it may be most appropriate to develop microadaptive techniques that allow managers to build understandable, implementable satisfactory solutions in a progressive and iterative manner. In fact, by using this approach over a period of time, managers and developers may learn that some of these problems or partial problems do have optimal solutions and they will then be able to develop optimising models that are valid, with solutions that are acceptable and implementable.

(5) A microadaptive approach (prototyping) can be used for system development as well as for solution generation. Prototyping has been used successfully in the development of management information systems and decision support systems (see Robak, 1989) and may be especially applicable for the solution of large, ill-structured problems since it is likely that neither managers nor developers will know, initially, what combination of techniques and tools will be most appropriate for a situation.

(6) According to Committee On the Next Decade in Operations Research (CONDOR, 1988), simulation is currently the most widely used modelling technique and it is likely that the underlying structure of these large, integrative, multi criteria and multi decision maker systems will be simulation based. In some cases the complexity of the problems are such that there is a better chance of success using qualitative methods and heuristics (CONDOR, 1988). That is not to say that mathematical programming and other more elegant techniques will not be used. In fact, I would expect that, once the overall system structure is built, you will find that many more sophisticated techniques will be incorporated than are in use today. The difference will be that they will be understood to indicate possible partial solutions in the larger problem environment.

(7) Although expert systems are a current fad that are too often applied to the wrong kinds of problems, they will become more important as part of a larger decision support environment. They will rarely (if ever) be developed to substitute for the knowledge of managers. Instead expert systems are more likely to be used by managers to: incorporate, integrate and test the significance of data; integrate, coordinate and validate particular models; interpret information and test alternatives against disparate evaluation criteria.

Some of you may realize that the foregoing is quite closely related to the principles of design, development and implementation of decision support systems. That is not surprising since it could be said that DSSs are where operations research and information systems technology merge. If it is accepted that most of OR research and practise is primarily involved in problem-solving, then operations research IS decision support.

## CONCLUSIONS

The decision environment for forest operation managers is changing. Many impediments to the implementation of operations research technology have been reduced. Data availability and computing power have increased dramatically and will continue to do so in the foreseeable future. The continued flattening of the managerial hierarchy and increasing complexity and sensitivity of the problem environment require that industry place more sophisticated tools in the hands of its managers - and demand that they use them. A corporate culture which accepts shoddy analysis, planning and control is on the wane. Nevertheless, development approaches which have won limited acceptance in the past are unlikely to be acceptable in the future. For those of us working in forest operation OR, perhaps the greatest contributions we could make would be to concentrate more on decision processes and spend more time developing better APPROACHES rather than more sophisticated models. We must not hold dogmatically to a limited set of modelling techniques since they each have their strengths, weaknesses and place. An eclectic selection of tools must be chosen in order to satisfy the needs of a multi-objective, multi-operant decision environment and a great deal of effort must go into learning how to integrate them.

Finally, we must beware becoming too enamoured with the wonders of new technology. Just because a larger LP model CAN be built doesn't mean that it SHOULD. We must learn how to incorporate qualitative decision criteria. We should keep abreast of research in related sciences, for we may gain more from studies of cognitive processes than those in the area of parallel processors. Perhaps, as some science fiction writers point out, the "final frontier" will always be the human mind, but that should not be an excuse for us to leave it to the last when we develop systems intended to help solve human problems.

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# FOREST OPERATIONS - PROTECTION TECHNIQUES

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FDC: 31: 46: 41

## SUMMARY

During the last 5 decades, forest work has changed from hard manual labour to highly mechanized work. Some of the most efficient methods have increased productivity 10-20 times. However, powerful machines and operational methods have created some damage in the forests. Scientists, belonging to Division 1 and 2, have investigated these damages and their influences on the forest environment and growing stock.

Scientists within Division 3 have started to investigate damaging forces and stresses. This paper gives examples of such investigations and proposes a new Subject Group on Forest Operational Protection techniques within Division 3. The Subject Group may be organized into working parties, for example:

-.01 Soil compaction and damage on forest soils and plants caused by forest machines and working methods.
-.02 Erosion in steep terrain, landslides and avalanches caused by construction work or operational methods.
-.03 Snow compaction, snow slides and avalanches.
-.04 Machines and operational methods for spraying or other practical efforts against industrial pollution (i.e. acid precipitation).
-.05 Forest fire detection, supression and controlled use.
-.06 Harvesting in sensitive areas.

## HISTORIC REVIEW AND BACKGROUND

The work in the forests was originally carried out by manual labour, and caused little damage to the forests and forest environment (some possible damages were not recognized). Cutting and felling was done by hand. The logs were transported by animals or along streams, lakes, or rivers. This was the situation for forest work in 1890 when the Austrian forestry scientist BÖHMERLE took the first initiative concerning international cooperation on forestry research. This led to the foundation of the International Union of Forestry Research Organizations (IUFRO). During the first congress of the Union in Eberswalde in 1892, the main topics were silviculture, forest biology, game and hunting. Multiple use forestry is not new in the IUFRO-family.

During the first 50-60 years of IUFRO's 100 year history, forest work and operations was of little interest to the research organizations and had little attention in IUFRO.

Industrial thinking was introduced by Sir Frances BACON as early as 1620 with the proverb "knowledge is power". As a result around 1850 the industrial revolution started. It had an enormous influence on the industry, especially after 1900. Forestry, however, was affected very little by this revolution. Most forestry work was still carried out manually.

Mechanization was applied early to the heavy work in forests with big timber. On the American West coast donkey yarders replaced teams of oxen in 1885 and Benjamin HOLTH constructed the first crawler tractor in 1904. During the Pasific Coast Logging Congress in Seattle in 1909 the need for a university course in logging was strongly emphasized. The first courses started in 1910-1911. The main goal was to qualify logging engineers to deal with mechanized operations. Fast development during the following 40 to 50 years resulted in heavy operations with high efficiency which sometimes resulted in enormous environmental damages. Reaction from the community could be foreseen, and it came.

In Europe a scientific approach to forest operations was initiated in 1927. Professor Hugo HILF from Eberswalde announced a new scientific subject: "Forest work science". This was the same year that professor MATTSSON MÅRN started forest work studies in Sweden, and Sønnik ANDERSEN made ergonomic studies of forest workers in Norway, and Alexander KOROLEFF began his work in the Woodland Section of Pulp and Paper research institute of Canada. 1927 was an important year for forest operational science.

After the second world war, the labour cost grew rapidly. Manual labour costs have increased more than both machine costs and timber prices. The need for development in working methods was appreciated.

IUFRO was reorganized in 1948. Forest work was included in the Unions research program and became one of the Union's 12 Research Sections with the name OPERATIONAL EFFICIENCY. The main emphasis was placed on the development of efficient and cost saving working methods and machines.

A better understanding of this science was growing. Scientists agreed that research on forest working activities should not be limited only to efficiency, but should be given a broader approach (ergonomics; forest machines; construction work; operational methods and economy; terrain classification; transport and operational planning; and correlation between operation, silviculture and environment).

During the meeting of Section 32 in Montreal 1964 (26 years ago) the name was changed to FOREST OPERATIONS AND TECHNIQUES.

In 1971 IUFRO was reorganized at the XV IUFRO World Congress in Gainesville. The Research Sections were transformed into Research Groups (Subject Groups and Project Groups). The Research Groups were coordinated into 6 Divisions. Division 3 coordinates the Research Groups within FOREST OPERATIONS AND TECHNIQUES.

During the last 5 decades forest working methods have changed from manual labour to highly mechanized operations.

The productivity of highly mechanized operations was often 10 to 20 times higher than the previous manual labour. The positive effect of this development on operational economy has been necessary in order to keep up with post-war increases in manual labour costs.

The high efficiency and productivity of modern forest machines had consequences. Damage to the forest floor, growing stock and environment happens frequently, especially after careless machine operation.

Forest research efforts may lead to better operational methods and machines. This will be an important challenge for the forest operational scientists in the years to come.

## CLASSIFICATION OF FOREST SOILS AND TERRAIN

The correlation between forest machinery and operational methods on one side and terrain-conditions on the other has been applied in scientific research and practical operation by means of terrain classification. In Norway, terrain classification was done as part of the 1954 National Survey of the nations forests. Since that time the forest terrain has been classifield four times: 1954/57, 65/67, 70/73 and 82/85 (SAMSET 1975). The correlation between the forest conditions and the terrain classes were tested.

The weakest point is the bearing capacity of the forest floor. LÖFFLER (1988) has worked out a classification of forest soils according to the sensitivity and risk of soil damage.

Löfflers excellent work is a basis for five sensitivity classes which will be applied in practical forestry in Germany.

LÖFFLER (1988) suggests that many of the investigations which have been carried out so far are based on measurements of the damages caused by existing machines. He defined such measurements as functional because the damages may change with the development of better machine construction. Some of these investigations are plowing deeply. The measurements give information about the soil, the soil structure, the hydrology, the vegetation etc. (BARNES et al. 1971, GOLOB 1982, HILDERBRAND 1983, FROEHLICH 1976, WÄSTERLUND 1988, BEEKMAN 1987 and many others).

## Action, reaction and interaction

The functional description of forest soil is mainly resticted to the soil's reaction to operational activities. There exists a mutual interdependency between the vehicle and the forest floor during machine movement. The action given by the stresses and forces from vehicles or machines produce reactions in the soils. It is necessary to investigate these interactions in order to find a descriptive classification of the soils so limitations for weight and machine power can be set for individual soil types. This is strongly stressed by several scientists. (BEKKER 1969, SCHOLANDER 1973, SAMSET 1987, BEEKMAN 1987, WÄSTERLUND 1988 and LÖFFLER 1988).

## The soil's reaction to stresses and forces produced by vehicles

Scientists from many countries have investigated the changes in agricultural soil strucure caused by compaction and erosion. Information is available about problems such as the internal stresses and structure of the soil, water tension, water conductivity and air permeability (BARNES et. al. 1971 and many others). Agricultural and forestry experiments show the influence of soil compaction and erosion on the soil fertility and plant growth. Some of the damage to agriculture soils may be overcome by using cultivation methods and equipment to prepare the soil. This is usually not done in forestry. Forestry often solve such problems differently than agriculture. Good examples are given in reports by FROEHLICH et. al.(1976, 1984), BREDBERG and MARKLUND (1984), BEEKMAN (1987), BOOL et. al. (1988) BROWN et.al. (1988), and WÄSTERLUND (1988).

## Vehicle mobility, trafficability and stress on forest floor

The research findings mentioned above show that it is possible to reduce actional forces on the forest floor by new designs of forest machines, e.g. tires, chassis, etc. Information about changes in machine design, working methods, road construction etc., must be based on forest operational research.

We may illustrate such operational experiments and investigations by a few examples:.

## Action from single wheel

The knowledge about the action on the ground from mobile machines must start with investigations on single driving wheels or tracks. This has been stressed by LÖFFLER (1988) and others. DWYER (1987) used a test-unit to compare various tires and wheel constructions (NIAE single wheel test vehicle). He found, for example, that medium width tires with medium inflation gave better efficiency than a wide tire on certain soils. Single wheel test-units may give us more information about such problems in the future.

The Norwegian Forest Research Institute has constructed a single wheel test unit for powered single wheels (SAMSET 1987). There exists a relationship in a driving wheel between the wheel load (Q) the friction (the shearing forces between the wheel and the ground (G), the rolling resistance of the driving wheel (R) and the traction or braking forces of the wheel (T).

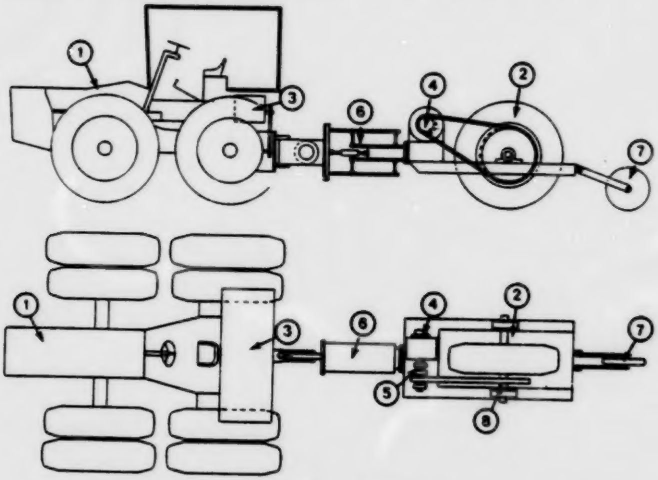


Fig. 1 Test-rigg. Norwegian Forest Research Institute.

① Leading tractor. ② Test wheel. ③ Hydraulic pump giving torque to the testwheel. ④ Hydraulic motor driven by pump (3).
⑤ Instrument for measuring the driving or braking torque.
⑥ Instrument for measuring pull and braking force.
⑦ Wheel to measure the travelling distance.
⑧ Measurement of the revolution of the testwheel. (Slip measurement).

The test unit (figure 1) consists of a leading tractor and a test wheel. The test wheel may be changed. It is possible to replace the wheel with a bogiee.

The leading tractor is equipped with a hydraulic pump which powers a hydraulic motor that propels the test wheel.

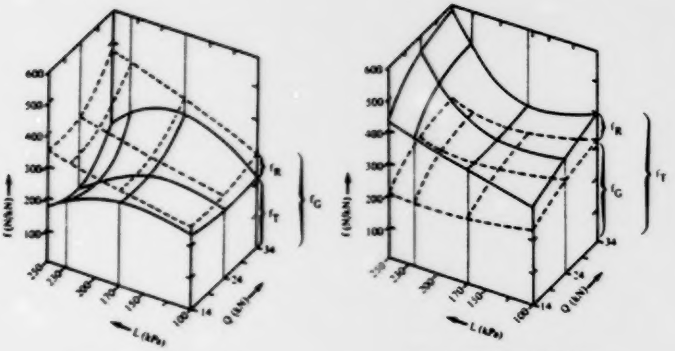
The torque of the test wheel can be varied by varying the oil delivery from the pump. The direction of the oil can be changed. This gives the ability to brake the test wheel. The forces are then tested with varying tires and varying weights on the wheel, while measuring the traction, shearing force, rolling resistance and slip.

As an example of how this test unit is being used to measure the complex of action forces on the ground, we may show the results from testing the two following wheels on a fixed compacted snowroad: Good Year 16,9/14 - 34 8 Ply Rating bias ply tire and Michelin 16,9 R 34 BIB\X MI8 radial tire. The two test wheels were tested with various inflation pressures (100 - 170 and 230 kPa).

$Q$ = Wheel load on ground surface    kN
$L$ = Tire inflation    kPa
$G$ = Shearing force between wheel and ground surface    kN
$R$ = Rolling resistance    kN
$T_1$ = Drawbar pull    kN
$T_2$ = Braking force    kN
$S_p$ = Slip. Percent.    %
$f_R = R + Q$ = Coefficient of rolling resistance    N/kN
$f_G = G + Q$ = Friction coefficient between wheel and ground surface.    N/kN
$f_T = T + Q$ = Traction coefficient or braking coefficient    N/kN

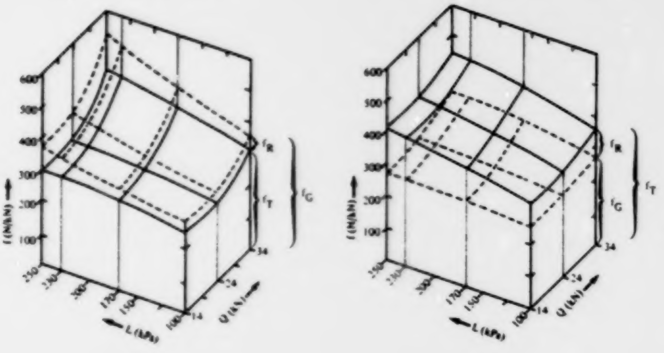
The three-dimensional diagrams in figure 2 illustrate these connections between the wheel load (Q) and the tire inflation (L) and the coefficients of rolling resistance ($f_R$), friction ($f_G$) and traction ($f_T$) and the resulting action on the ground surface. They show, for example, that the rolling resistance of the bias ply tire increases much with the increase in inflation pressure, because the wheel digs into the snow cover. This is not the case with the radial tire.

It is our intention to use the NISK SINGLE WHEEL TEST UNIT on various forest floors. The inter-action between the active forces from the driving wheel and the re-action on various types of soil surfaces in the forest floor may give information for future developments.



A) Bias ply tire. Pulling.

B) Bias ply tire. Braking.



C) Radial tire. Pulling.

D) Radial tire. Braking.

Fig. 2 The variation of rolling resistance ($f_R$) friction coefficient ($f_G$) and coefficient of traction or brake ($f_T$) with the tyre-inflation (L-kPa) and the wheel-load (Q-kN).

## ACTION DUE TO CHASSIS CONSTRUCTION

The chassis construction of a tractor or a vehicle may cause additional forces on the forest floor. The Swedish University of Agricultural Sciences, Department of Operational Efficiency has tested such forces on a forwarder equipped with bogies in the front and rear of the tractor. By equipping each wheel in the four bogies with instruments showing torque, shearing forces and traction forces interesting results have been found (BREDBERG and MARKLUND 1984, OLSEN and WÄSTERLUND 1988).

An articulated frame steered tractor may have different revolutions per minute on the outer wheels than on the inner wheels. Sometimes a differential lock is used which gives extra shearing forces.

The average revolutions on the front axle are sometimes different than the average revolutions on the rear axle during turning. If such vehicles are not equipped with a central differential it gives additional friction forces.

When the load is unevenly distributed on front and rear axles the rolling radii may be different, which gives differences in the revolutions on the various axles. This increases the shearing forces.

The two wheels in the bogie are usually directly connected with a chain or gear. When the bogie passes an obstacle the bogie tips against the revolution of the driving axle or in the same direction as the revolution of the driving axle. Since there is a fixed connection between the two wheels the movement of the bogie causes and extra torque between the wheels. This causes an additional friction between the two wheel surfaces. The result shows that this extra friction force may be double that of the ordinary friction force alone.

If the vehicle is equipped with crawlers (such as track laying tractors) the bearing surface of the the tracks is usually higher than the wheels and distributes the weight better on the ground surface. This reduces the specific pressure on the ground. However, the internal part of the rolling resistance is usually higher on crawlers than on wheels.

When a crawler tractor with skid steering turns, the tracks have to slide sideways to a new angle which gives extra shearing forces. This is especially noticeable if the turn is activated by braking one of the crawlers.

When adding up differences in shearing forces between the wheels or between the front and rear part of crawlers, the resultant shearing force may reach very high values. This may result in damage to the forest floor, roots and stems of living trees due to chassis construction.

## SKID ROADS, SKIDDING AND YARDING OPERATIONS.

On weak ground with limited bearing capacity the damaging action on the forest floor may be reduced by directing the transport along strip roads, skid roads etc. The wood may be collected with winch skidding, hydraulic loaders or long telescope cranes. The bearing capacity of the skid roads may be increased with gravel, stones or with tree branches from the harvesting machine.

In steep terrain two different types of skid roads have been used.

## Steep skid roads for downhill transport.

Tractor-skidding along steep skidroads has sometimes replaced cable crane operations. The tractor and the ground skidded load break roots and vegetation and damage the soil. In addition, rainfall may cause enormous erosion. BAKKE (1986) has measured up to 400 $m^3$ of eroded soil per kilometer skid road.

Terrain with stones, rocks and boulders is more resistant to such damages than hillsides with few rocks and stones in the soil.

The soil texture is important. Under Norwegian conditions, loamy soils usually have more erosion than stony gravel soils with high internal friction between the grains of sand. Usually, cable crane operations give less damage than downhill tractor operations. If the ground is steeper than 40 per cent, a cable crane operation would be preferred from an environmental point of view (BROWN and JEMISON, 1988).

## Contour skid roads.

The skid roads may be laid out over the felling site parallel to the terrain-contours, often with 20-40 m spacing. These are lightly constructed roads without stabilization. Sometimes they are laid out parallel to terrain contours and sometimes with a certain slope. The construction of the roads may be done by the front blade on the skidding tractor or with a hydraulic excavator.

This method may be good for example during thinning operations if the soil has good stabilization (surfacing, drainage etc.). On weak soils, however, the dense parallel network of skidroads may break the stabilization between various soil layers. Heavy rainfall and snow melting may lead to heavy erosions and land slides. Examples of such erosion have been reported in mountainous conditions in Norway, and in the Interior Mountains of British Columbia.

Under such conditions and when the terrain is steeper than 40 per cent, a network of access roads and feeder truck roads with 300-400 m spacing may be better for the environment. Short distance cable cranes can bring the wood to the feeder roads. Examples of these solutions are shown in the Moroto Forest in Japan and in Silvifuturum in Norway (SAMSET, 1978 and MOROTO, 1979).

## SNOW COMPACTION AND AVALANCHES OF SNOW IN STEEP TERRAIN.

In a cold climate, snow often covers the ground during winter. The snow density increases from 0,01 up to 0,60 kilo or more per cubic desimeter due to sublimation, melting metamorphosis, and plastic compaction.

This metamorphosis is sometimes being used in the construction of compact snowroads. By compaction, the snow grains are pressed closer together, and by means of leveling equipment, small snow grains mix with big grains and cold grains mix with warmer snow grains. This increases the hardening of the snow so that the compact snowroads can carry tractor loads or heavy truck loads. This method may be used where it is difficult to construct roads, on ground with many obstacles, and on forest floors with weak bearing capacity.

The temperature in a snow layer is usually higher near the ground, and gets colder towards to the surface. The air penetrates upwards throughout the layers of snow, and as the temperature is reduced, the ice molecules migrate from the voids and attach themselves to the snow crystals. In a coarsely-grained snow, therefore, a new crystal formation gives prismatically formed crystals. This usually happens in the snow layers nearest the ground, and the result is a sugar-like snow that is lacking in cohesive strength.

A heavy snow layer on top of sugar-like snow can easily slide downhill on steep mountainsides. It may be useful to leave some trees or to construct snowsheds in order to break the snowslide. Measuring points of snow profiles can be used for warning of avalance danger (SAMSET, 1956).

## FOREST FIRE PROTECTION AND USE.

The protection against forest fire has many aspects of biological, physical and even political nature. Fire is sometimes used in prescribed burns as a managment tool.

In this context we concentrate on the operational aspects, the equipment and the methods for fighting or beneficial use of the forest fire. Such problems are related to other problems within forest operations and the scientists dealing with fire methods may have a natural place in Division 3 for international cooperation. Sometimes specialized equipment is needed. Logging machines, road-building machines and other forestry machines with auxilliary equipment can be used for fire management in the forests. In many circumstances this combination gives a more efficient and less costly method of fire fighting.

## HARVESTING IN SENSITIVE AREAS.

Under many circumstances, joint production of timber products and other forest uses are compatible. Special harvesting methods and machines may be needed in critical areas of wildlife habitat, riparian areas, shorelines, scenic areas, and so forth. Various studies are needed and results showing various techniques will have interest.

## CONCLUSIONS AND PROPOSALS.

During the last decades, forest work has changed from heavy manual labour to highly mechanized forest operations. While productivity has increased parallel to machine evolution, careless use of the most efficient machines can create damage to the growing stock and forest floor.

The consequences of such damages are investigated by scientists belonging to Division 1 and 2. Their studies concentrate on the effect of forest operations on the forest environment.

Scientists within Division 3 have the necessary knowledge to study forces, stresses and other actions on the forest environment caused by construction work, operating machines and operational methods.

The time has come for Division 3 to form a cooperating body in which scientists from forest operations can meet to discuss research methods and results from their investigations of forces, stresses, and other influencing factors which may have damaging effects on forest environment and growth.

Such a body may be organized in the form of a new Subject Group within Division 3, for example with the name:

FOREST OPERATIONAL PROTECTION TECHNIQUES.

The object of the Subject Group can be defined as follows:
The science comprising investigations of all active stresses and forces, caused by construction work on forest lands, forest machines and working methods in order to develop better operational techniques, and activities. The goal is to reduce damaging effects on forest environment and growing stock caused by operational activities or by nature (including avalanches, landslides, forest fires etc.). The Subject Group may be organized into the following Working Parties:

-.01 Soil compaction and damage on forest soils and plants caused by forest machines and working methods.
-.02 Erosion in steep terrain, landslides and avalanches caused by construction work or operational methods.
-.03 Snow compaction, snow slides and avalanches.
-.04 Machines and operational methods for spraying or other practical efforts against industrial pollution (i.e. acid precipitation).
-.05 Forest fire detection, suppression and controlled use.
-.06 Harvesting in sensitive areas.

It may be practical to combine some of these groups.

December, 1989
Ivar Samset.

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# ERGONOMIC RESEARCH FOR THE FUTURE

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## SUMMARY

If forest and woodworking industies really have to become humanized, drastic developments will have to take place in the design of man-task-systems, both technically and socio-organizationally.

For three situations of different degrees of mechanization suggestions for improved safety, health and well being of the workers have been developed.

For the developing countries special attention if given to the development of appropriate personal protection equipment and the nutritional health status.

For the moderate and highly mechanized situations special attention is given to the development of new machine systems resp. operating systems and work organizations.

May these brain storming ideas about how to reach optimal working circumstances during the last decade of this century inspire ergonomists and manufacturers to the benefit of the workers in forestry and woodworking industries.

Keywords: design of work systems, work organization, safety, health, well being.

## INTRODUCTION

With this 14th World Forestry Congress we move into the last decade of the 20th Century. What can we expect during this last decade which has not been realized during the proceeding years?

Upto and including the 10th World Forestry Concress in 1948, contributions on operational research, but alone ergonomic ones, did not appear in the proceedings. During this period, research on operational matters including attention for the forest labourer were practically at a standstill.

Suddenly there was a change. Within IUFRO a working group on woodharvesting was set up in 1948, with the result that 14 publications were presented during the next World Forestry Congress in Rome, 1953, on matters relating to operationel research. Three of these contributions were on ergonomic matters! All of these ergonomic contributions were dealing with work fysiology, one of them even included nutritional aspects. During the fifties attention was paid also to matters in relationship to noise and vibrations, this as a result of mechanization in forestry work.

Research policy did not change much in the following decade. A start however was made, in the direction of system approach by making use of checklists.

During the seventies, increasing attention was paid to psychological aspects of forest work, as well as to problems on safety matters. Also during this period, a start was made to develop ergonomic job design.

During the eighties the research policy of the previous decades was further developed. Moreover special attention was given to specific topics related to problematic groups of workers such as workers victum to occupational accidents and deseases (Seminar in Kuopio, 1987) and on workers in tropical and developing countries (Seminar in Wageningen, 1979; Workshop in Olmotonii, 1985 and the PET training courses, started in 1982).

Once again the question arises, what can we expect from this coming decade? I personally think very much indeed as technological development is rapidly progressing. Ten years ago we did not have personal computers in all our offices, neither did we use faxes, no computers were used in our harvesters or robots not in industry on the scale we have today.

Which technological possibilities will we have in ten years time, when we leave this century? We can only guess.

For those working in the field of ergonomics, it is very important now to make use of the technological progress to better the circumstances of forestry workers in the field, this in association with managers and engineers. If we neglect to do so adequately, men will be subjected to technology, as has been the case in the past, with the result that many forestry workers now in one way or the other have complaints or are injured.

Special attention, I think, should be given, to developements in tropical countries. Due to the specific circumstances in these countries, it is very difficult to bring our technological developments into practice there. Special research should be carried out on ergonomic and safety problems in these countries. I would like to refer to the special contribution of Strehlke (1990).

## PROBLEMS AND FUTURE NEEDS

Which problems will need to be solved during the coming period? The enormous socio-economic differences in the world are also found in forestry and the woodprocessing industries and it is impossible to give overall solutions for these situations. Mondially one can say that in many cases the problems exist as they did ten years ago. Therefor I would like to follow the line set out by Ager (1978), in which he describes the ergonomical problems.

He does so through three stages of development which are characterized by three levels of mechanization i.e.

- Situations with mainly manual techniques under unfavourable socio-economic and climatic conditions.

- Situations with moderate mechanized techniques under comparatively favourable socio-economic and climatic conditions.
- Situations with highly mechanized techniques under favourable socio-economic and climatic conditions.

By using a systematic approach concerning the described problems, the following should be taken into account when solving the problems:

1. Identification of the problems which are characteristic of the specific work systems.
2. Analysing the causes of the problems, direct and indirect.
3. Suggestions for solving the problems or indications in which direction solutions can be found.

Important for the above mentioned is, that difference should be made in fundamental and practical research work. Within this approach distiction should be made between technical, human (fysiological, psychological) and socio-organizational research.

Finally within the large field of ergonomics priorities and posteriorities have to be distinguished based on the socio-economical differences of the situations. According to the hierarchic piramid of needs of Mastov (1954) firstly the fysiological and biological needs have to be met, followed by the needs for safety and order resp. needs for social contacts and, finally, the needs for honour and respect. This line has been maintained in the choise for priorities in research.

## SITUATIONS WITH MAINLY MANUAL TECHNIQUES UNDER UNFAVOURABLE CONDITIONS

They regard the developing regions with special attention given to those areas with tropical circumstances. Problems in these areas which have to be solved also in the near future are:

- the poor working capacity of the labourers, due to
- ill health and bad nutritional status;
- heavy physical work, often in combination with
- heat stress, and

- high accident rates.

References in this respect are Apud et al. (1990), Dickson (1990) and Strehlke (1990).

By seeking solutions for the problems mentioned an attempt should be made to find solutions appropriate under these unfavourable climatic and socio-economic conditions. At the same time they should relief the vicious circle of poverty.

## Identification of problems

For reasons of signalling continuous research will have to be carried out after the presence and magnitude of the bottlenecks of working capacity, health and nutritional status, workload of different activities and the number and the seriousness of accidents related to workers catergories in forestry and woodworking industries.

## Analysing of problems

Applied research has to be carried out regarding the causes of the low working capacity, and the large number of accidents, distinguished in fysiological, psychological and socio-organizational origin.

Fundamental research regarding:

- The psychological causes for the accident proneness of special categories of workers; including the question whether European models are also valid for workers in developing countries (Kanninen, 1986).
- The influence of nutrition and heat, in combination with the use of extra liquid and salt, on the working capacity.
- The relation between working capacity and acceptable work load.

## Solutions of problems

Technical research has to be carried out regarding the design of appropriate personal protection equipment (ppe's), which must be simple locally produceable, as well as being acceptable for tropical situations.

Human and socio-organizational research has to be carried out regarding the design and evaluation of work systems including solutions for the signalized bottlenecks of health, nutrition and accidents, for instance via growing and distribution of sufficient and varied foods, the supply of adequate implements, of ppe's, and the introduction of work organizational measures by which heavy work is carried out during the more cool hours while light work or rest is introduced for the hottest hours (so called job enlargement).

The introduction of these solutions should be preceded by dissemination and training campaigns to give it chances for succes.

For the realization of this type of research and for the transfer of the recommendations into practical measures close cooperation is necessary between research institutes, ministeries of forestry and labour, and if necessary development agencies as a financial and organizational medium (Staudt, 1989).
Following these procedures the vicious circle of poverty (Ager, 1978) might be relieved.

## SITUATIONS WITH MODERATE MECHANIZED TECHNIQUES UNDER COMPARATIVELY FAVOURABLE CONDITIONS

This regards the developed countries in the temperate and subtropical climates, where the socio-economical circumstances are relatively favourable. However conditions don't cause further mechanization, e.g. because of small scale, multiple use forestry, or low margins of profit. Manual work often in combination with motor driven manual equipment is often practised in combination with relatively simple (and sometimes out of date) machinery which does not meet the ergonomic criteria. This situation also can be met in more advanced developing countries.

Main problems in cutting here are:
- the large number of accidents;
- the large number of physical complaints of deafness, "white finger disease", back pain, heavy work load etc.

In this respect reference can be made to Pontén (1990) and Lipoglavšek (1990).

### Identification of problems

Continuously signalling research has to be carried out after the presence and magnitude of the bottlenecks mentioned, viz. accidents, deafness, etc.

### Analysing of problems

Applied research has to be carried out regarding the causes of the bottlenecks mentioned, distinguished after physiological, psychological and socio-organizational origin.

Fundamental research after:
- the effects of vibration on the human body and the improvement of the criteria and limits for the exposure to composed vibrations and shocks.

- the effects of working postures and movements on the human body and the improvement of criteria and limits for the exposure to bad working postures and movements.

## Solutions of problems

Technical research has to be carried out regarding the design of ergonomically justified machinery and implements such as:

- the development of sound and vibration reduced chain saws. Principles are often well known, but for financial and practical reasons manufacturers fail in the development and the application of these principles.
- the development of the so called wood caddy tractor (iron horse), towards a simple work bench; trees should be winched on to the vehicle to be processed either by a processing head or manually by a chain saw on a anthropometrically justified working hight; or
- the design of a complete new concept of a chain saw not burdened with the present disadvantages and based on the following characteristics (and ergonomic advantages):
  * remote controlled (elimination of vibrations and reduction of noise);
  * self driven (reduction of physiological and biomechanical load);
  * a sawing resp. a processing device fitted to a hydraulic boom;
  * a clamping device in combination with the sawing resp. processing device or a hydraulic boom, for lifting up or pushing down the tree (elimination of physiological and biomechanical load);
  * bringing down hanging trees according to the principal of the felling sulky (Skaar, 1981);
  * this concept could be combined with either the principle of the wood caddy tractor (iron horse) (Nordfjell, 1986), or a robot;
  * simultanious operation of more units by one operator;
  * conditions for this device are a light weight, relatively simple and not to expensive device.

Socio-organizational research has to be carried out regarding the restriction of the functional overload (causing repititive stress injury) by reduction of the exposure time by work organization, viz. job rotation and job enlargement. For details see next paragraph about high mechanized techniques.

For research-organizational aspects see also next paragraph.

## SITUATION WITH HIGHLY MECHANIZED OPERATIONS UNDER FAVOURABLE CONDITIONS

This situation is realized in the richer industrialized countries with large forest area's in the temperate and colder climates. Wages there are high and financial space is available for more investments to increase the degree of mechanization.

Main problems in forestry and woodworking industries are:
- absence of physical load causing overweight of operators;
- restricted working postures in combination with;
- functional overload of special joints and muscles causing repetitive stress injuries (RSI);
- monotony in combination with mental strain caused by continuous concentration on higly specialized tasks;
- social isolation.

For forestry additional problems are:
- vibration, shocks and in a restricted way, noise generated by heavy machinery.

For woodworking industries additional problems are among others:
- air pollution by wood protection agents.

Causes are the fast technological developments of these industries in combination with little attention from technical designers for ergonomic system design, and failing ergonomic research. For references see Leitass (1990), Pontén (1990) and Mäkinen (1990).

### Identification of problems

As a signal function research should be carried out continiously after the presence and magnitude of the bottlenecks mentioned above, viz. RSI, mental strain, monotony etc. and of course accidents.

### Analysing of problems

For applied and fundamental research reference can be made towards paragraph "The situation with moderate mechanized techniques" (see above), regarding criteria for vibrations and working postures as well as movements. Furthermore special attention should be given to socio-psychological research to the causes of stress and the possibilities and consequences of job design for operators.

## Solutions of problems

Technical research should be carried out on the feasability of:

- The design of mobile controle units for operators seperated from the operating units (harvesters and processors), in combination with remote controlled operations (resulting in elimination of vibration and shock exposure and reduction of noise exposure and risk for accidents).
  Moreover one operator could control more machines simultaneously. During road transport the control unit could be jointed to the operating units to function as a truck-trailer combination.

- The improvement of noise and vibration control of terrain vehicles; attention should be given to so called active control systems.

Socio-organizational research should be carried out on:

- Work organization and job design aiming to improve the social contacts and to reduce monotony and mental strain of operators in clearcut tree felling. One could think of the introduction of job rotation and job enrichment together with the installation of a large caravan serving as a mobile central office, with a workshop an administration office, a cantine and a cloack room. Similar solutions have been worked out for saw mills (Ager, 1980).

These solutions should contribute towards optimal task systems for operators of heavy forest machinery, regarding safety, health, mental load and in general job satisfaction.

Also problems of criteria and limits should be clarified so that operators and managers will know towards which degree human beings can be exposed without risks for health in the long run.

Realization of the aimed optimal work systems needs close cooperation between manufacturers of forest machinery, managers of forest industries and ergonomic researchers. For succesful introduction of these work systems, coopertion between research institutes and ministeries of forestry and labour will be essential, as to be able to anticipate the newest developments by extension, education and training.

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# SOME VIEWS ON THE STATE OF ART OF RESEARCH IN FOREST OPERATIONS AND TECHNIQUES

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## SUMMARY

The study of forest operations and techniques was established as a discipline in forest science around 1950 with somewhat varying "territories" at institutes and faculties. Work study is briefly reviewed and the reference of time consumption as the scale in physical models of technical work systems discussed. It is suggested that energy analysis of such systems should be more often used and that operational problems should be studied also in larger and longer perspective than what now is the case. The laws of energy and matter and "biophysical economics" might be most useful in such studies.

Keywords: forest operations and techniques, work study in forestry, energy analysis in forestry, biophysical economics.

## INTRODUCTION

As a contribution to a book published in honour of Ivar Samset on his 70th birthday, I was asked to write an historical and doctrinal account (Sundberg 1988) on the discipline of Forest Operations and Techniques (FOT). This paper highlights that essay and attempts to further pursue an inquiry into some epistemological issues of importance for FOT in the future.

The discipline of FOT now occupies somewhat different "territories" in forest science in different countries and at different institutions, seen as an adaptation to the needs and empty niches in border zones to the older, traditional disciplines. In Appendix 1 some relevant definitions of FOT are quoted. In my opinion the present definition of FOT, as in the IUFRO Statutes Division 3, is too narrow to stimulate a continuing adaptation of the discipline to changing forestry problem areas.

## FOT ESTABLISHED

It is suggested that FOT was firmly established as a discipline around 1950 through its international recognition by IUFRO as the Section 32 Operational Efficiency and by FAO through the setting up of the FAO/ECE Pilot Committee on Logging Techniques and Training of Forest Workers. The use of statistical theory in the design of the studies and in the computations of the data (e.g. regression analysis) are considered important for this recognition. Through these tools the stochastic nature of forest work could be mastered. The early integration of ergonomics into FOT research strengthened FOT's status and was also pathbreaking, useful and constructive.

The initiative in Canada to start a scientific FOT journal - Journal of Forest Engineering, published at the Dept of Forest Engineering, University of New Brunswick, Fredericton, N.B. - is greeted with satisfaction and all FOT researchers should now give it full support, e.g. maintain a high professional standard through contributions.

FOT research in the last 25 years has developed considerably, in particular by the use of a system approach in the analyses and syntheses of forestry operations. This is specially apparent in the studies of thinning operations by considering the impact of techniques on the forests and in labour studies by considering the socio-economic setting. Similar broadening of the scope of FOT research into energy and environmental impacts at large has begun and it is highly desireable that such methodological expansion of the studies is being improved by attempts not only to discuss such impacts qualitatively but also to express them quantitatively.

### Work Study

The genesis of FOT research was "work study" originating in the USA in the study techniques developed by Frederick Winslow Taylor (1856-1915). Quote "He approached problems which had been thought either not to exist or to be easily solved by common sense, in the spirit of scientific enquiry" Unquote (Walter 1921). Conceptually, it is suggested that work study involved a paradigmatic change in the economics of production, especially with regard to balancing the inputs of labour, energy and capital. Time or time consumption became the main measure of efficiency. This in turn was a consequence of the industrialization and of increasing use of energy as a subsidy to man power in production. Earlier, time played a much more subordinate role. For example, in agriculture the work was governed by the seasonal rhythm and the most important tasks simply had to be finished within a certain period. In the mining and steel industry, efficiency was most often expressed as unit of produce per unit of energy (e.g. charcoal, the supreme energy carrier of that time).

Even if additional criteria than time are now used in work study, time consumption remains the base parameter in our physical models of production. It is most unfortunate that this paradigm ruled when the industrialized countries in the period after the second world war attempted to transfer production techniques to the less developed countries, where a pre-industrial, largely agricultural economy dominates. The question for FOT research now is if a new paradigm is needed when we enter - as many claim - a post-industrial era in which new value systems are likely to evolve. Will time gradually fade from its dominating status in production planning? Which other values and criteria will then gain strength or emerge? We can only speculate on these questions but such speculations are not meaningless when it comes to timely modify our approaches in research to a world in change.

## Time and Energy

The oil embargo in the 1970's was accompanied by a worldwide movement for energy saving and conservation. However, the energy surplus in the 1980's focused the concern of society on environment degradations, which also can be looked upon as an energy issue, being a consequence of an extravagant use of energy. Forestry is basically a matter of transforming solar energy to goods and services demanded by man. All these aspects suggest that the energy factor will increasingly become more important in future and that energy analysis should more often be included, perhaps always, as an additional component in FOT research. In my experience, energy analysis - to map the flow of energy and matter in a production system - gives new and useful insights into its mechanisms and the interactions between the inputs. It also opens up possibilities to elucidate quantitatively the environmental impacts of technology, which are likely to grow in importance in most forest settings.

There can be little doubt that the forest resources will become more and more important in the future, not only for the supply of the traditional products like lumber, pulp and paper but also for other services and functions. This congress will give much evidence of this trend. The contribution of the forest resources for ensuring the earth's supply of energy is becoming increasingly important and the potential is up to now only marginally exploited.

A FOT study normally consists of one or several physical models of work operations or systems which then are evaluated in money terms using standard economic procedures. But economics, e.g. the neoclassical school, is now criticized by many for dealing with resource use in a too narrow sense not accounting for the biophysical foundation underlying production. This will be dealt with at other sessions of this Congress, e.g. at the sub-plenary session on Thursday, August 9, "Forests for Industrial Requirements including Energy - Assessment, Inventory and Supply", by J.C. Mercier, A. Reddy, B.C.Y. Freezailah and P.O. Nilsson & U. Sundberg.

Criticism has in fact been addressed to the science of economics for some time, as recently reviewed in a book by Martinez-Alier (1987) and it is now taken up by many scientists with an ecological background, spurred by the break through and achievements of system ecology. At bottom, the view is that energy is the source and control of all things, all values and all actions of human beings and nature. The scope is to integrate ecological economic perspectives into social sciences, to expand neo-classical economic analysis to account for the biophysical foundation underlying production, to expand ecological analysis to include human activity. To me, there is every reason for FOT researchers to observe and even take part in this dialogue. We study and advise on the design of forest operations and our results bear strongly on the flow of energy and matters in forestry. The relevant question to FOT research is "whether energy analysis, being of necessity circumscribed by the laws of physics, is ultimately of greater utility in predicting and analyzing economic activity compared to economic analysis which has no such constraints" (Sundberg & Silversides 1988 p123).

It is now often said that we are on the threshold to a new era in the history of man, entering the post-industrial society. It seems that this belief largely is viewed as a consequence of increasing dominance of white collar work and of mechanization and automatization of physical work. I would suggest that if a new era is in being, the reasons are more fundamental. This table is an attempt to picture the landscapes of the eras.

Table 1: Picturing the landscapes of the eras.

| ERA | MAIN ENERGY SOURCE | DOGMA TENET | NORM | WEALTH | THEORIES GUIDING ACTIVITY |
|---|---|---|---|---|---|
| Pre-Industrial | Biomass<br>Wood<br>Charcoal<br>Wind | Steady state | Stability | Land | Supremacy of ruler, given by god(s) |
| Industrial | Fossil fuels,<br>Hydro power | Growth | Change | Money | Economics |
| Post-Industrial | Fossil fuels (outgoing),<br>Hydro power,<br>Nuclear (outgoing),<br>Biomass,<br>Other renewables | Sustainability | Ecological balance | Quality of life | The laws of energy and matter |

Tied to, or emerging from these concepts are the **values** on which society is built - changing, evolving, shifting emphasis over time - and on which FOT research establishes its scope and criteria. It is not suggested that we should now throw out our present norms but that we should think bigger and longer. Perhaps biophysical economics will help us in doing so and in adapting our discipline to the realities of the future.

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# APPENDIX I

## SOME DEFINITIONS OF FOREST OPERATIONS AND TECHNIQUES (FOT)

1. Section 32 of IUFRO, Operational Efficiency (1949-1971):
Efficiency studies in all branches of forestry. Improvements in equipment, methods and working and organization for the extraction, grading and transport of forest produce.

2. Division 3 of IUFRO, Forest Operations and Techniques (1972- ):
Tree harvesting, delivery and processing operations; Operational methods in the establishment and treatment of stands; Operational planning and control, work study; Forest operations in the tropics; Forest operations under mountainous conditions; Harvesting and forest energy; Ergonomics; Small-scale forestry; Harvesting and utilization of tree foliage.

3. Terms of References of the FAO/ECE/ILO Committee on Forest Working Techniques and Training of Forest Workers:
"to foster international collaboration with regard to improvements of forest working techniques and training of forest workers in logging and other forest operations in order to support national efforts aimed at increasing productivity and improving the standard of living of forest workers; special attention to be given to increasing the efficiency of labour, reducing at the same time the efforts of the workers, prevention of accidents and reduction of waste".

4. For the purpose of this paper (Sundberg 1988) the following definition of the discipline Forest Operations and Techniques (FOT) is suggested:
The discipline "Forest Operations and Techniques" is the study of the interaction of labour and machines with the forest. It involves an understanding of the relationships between labour, technology, the forest resource, forest industries, people and the environment. It becomes an approach to other, traditional subjects and disciplines rather than a subject itself. Yet, it is an academic discipline and a subject in forest science conducted with scientific rigour and the approach has important practical applications.

# BASIC TRENDS INUTILIZING TREE FOLIAGE

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## SUMMARY

The last four or five years have witnessed ample research on the chemical composition of the foliar fraction of tree biomass with quite a number of groups of substances recovered and ways of their application come into view. New trends in utilizing foliar extractive products emerge: repellents for pest control, fungicides, growth stimulants for agricultural and horticultural uses. The application of tree foliage based substances in agriculture open up possibilities for having pollution - free produce. Ways how the said substances could be used in medicine and veterinary science are shown.

Keywords: tree foliage, extractive substances, pest control, medicine

## INTRODUCTION

In view of the ever-increasing environmental pollution, pressing is a need for pollution-free, with reference to both production processes involved and ways of application, preparations such as growth stimulants for plants or drugs for use in medicine and veterinary science. Living plant material is known to have been, since times immemorial, used to meet these requirements, although this custom has, in our modern times, fallen in disuse for a variety of reasons, as profitability considerations, limited resource availability, inadequate industrial methods of processing and unintelligent utilization.

Tree foliage, a by-product in logging as it is, so far classed with residue, is a material amply available and easy-to-harvest, using the methods and machinery known. These considerations have served as the background for a research program on the utilization of the foliage fraction of tree biomass, with foliage-recovered substances for plant protection and foliage extractives for use in medicine as a part of it.

## EXPERIMENTAL METHODS

The efficiency of the preparations for plant protection have been tested using standardized for the USSR methods which include also toxicity tests and environmental impact evaluation. Medicinal preparations derived have undergone initial product testing, likewise, following the program and methods practicable in the USSR.

## RESULTS

Repellent SM-87 for horticultural use to keep off pests, Repellent RX-87 of antirodent activity and an insecticide to suppress plantlice and the like are some of the items, a co-development between a number of organizations has resulted in.

To illustrate the efficiency of the above products, tabulated are data for Repellent SM-87 (Daugavietis, Pinne, 1989).

Table 1

| Pest (in Latin) | Crop | Decrease in per cent of damage as against the control, (%) |
|---|---|---|
| 1 | 2 | 3 |
| Delia antigua Meig. | Bulb onion | 80-95 |
| Eumerus strigatus Fall.<br>Eumerus tuherculatus Rand. | Narcissus, hycinth | up to 90 |
| Delia brassicae Bouche | Cauliflower and head cabbage, garden radish, black radish | up to 90 |
| Centhorrhynchys quidridens Panz. | Cauliflower and head cabbage | 90 |

| 1 | 2 | 3 |
|---|---|---|
| Phullotreta memorum L., Ph.atra F., Ph.ondulata Kutsch. and other species | garden radish, swede | 60-70 |
| Psila rosae L. | Carrot | 85 |
| Authonomus rubi Hbst. | Strawberries | 70-90 |
| Taeniothrips simplex | Gladiolus | 70-80 |

The said repellent is being tested for other pests as well. The Institute of Horticultural Research in Great Britain has referred to it in terms of praise. Entomologists hold the repellent to be effective against insects chemoreceptor-oriented to their feed-on plant. An ambient permeated by volatiles (glycosides, volatile oils) other than those of the host plant disorients the insect. It is to be noted here that pests develop no adaptability to repellents derived from living plant material.

A similar effect is exhibited by Repellent RX-87, intended to protect orchard and nursery stock from hare, as well as to keep away rodents (mice) from storehouses, etc.

An insecticide recovered from Picea abies needles is effective against plantlice, Colorado potato beetle, blue flea and other pests. This insecticide is pollution-free, easy decomposing, non-toxic to hot-blooded animals, its efficiency has been field-tested.

Literature data suggest a possibility for recovering growth stimulants from conifer needles (Kolesnykova et al.).

Certain extractive substances derived from tree foliage show promise as medicinal preparations. Initial product testing for some of them is currently under way in the USSR.

In this respect, substance RSL-1/88-1"BF" is the most interesting one. It appears to be an immunomodulator selectively affecting humoral link of immune response and having nonspecific phagocytic activity of microphages; it can therefore be used in the treatment of various diseases whose principal pathogenetic mechanism is disbalance of the immune system, which is responsible for genetic integrity and uniformity of an organism, and for protecting the latter against living bodies or substances bearing genetically heterologous signs. Besides, RSL-1/88-1"BF" is an efficient antistressor and adaptogenic drug capable of protecting the immune system against depressive effects of chronic emotional stress and ensuring prophylaxis of various diseases associated with any degree of immunity disbalance.

Biological testing of the said substance has shown it to be completely innocuous, having no effect on reproductive function, inducing no undesirable mutations and having neither embryotoxic nor teratogenic effects (Bluger A. et al.1989).

Initial testing is also done on preparation HSP-3/87-89"F" for its reparative activity and effects on acid forming, enzymeforming and motor functions of the stomach on its electrophysiological activity. Tested is also preparation HSL-3/89-3"BF" for its antioxidant activity.

The above examples show a change-over from conventional practices of using overall extractives in cosmetics, or as fodder additives to isolation of individual biologically active substances to have resulted in new possibilities for the application of foliar extracts in medicine.

The research on the chemical composition of the Pinus silvestris and Picea abies foliar extractives has by now been completed in general outline. New programs for other conifers and some decidous species are being contemplated.

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# COMPETITION OF CENTRALIZED AND MOBILE PROCESSING
## - BASIC ASPECTS

S. 3.01 - 07

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## SUMMARY

In Central Europe mobile crane harvesters (single-grip grapple harvesters) are the high technology alternative to centralized processing at woodyards. High productivity, low costs and careful working favour the harvester, large yield of volume and value and also the possibility of harvesting in steep slopes are advantages of the woodyard. The research engages in the question, if the advantages of both systems could be combined.

## INTRODUCTION

A new situation arose because an increasing number of mobile harvester systems are being used. With the help of these machines it is also possible to harvest bigger trees up to a base diameter of 60 cm (24 in). Harvesters are even suitable for hardwoods. Nowadays harvesters are equipped with an electrical control and measuring system, data memory and sorting capability. The harvesting costs are low but the machines have high investment costs.

The damages of soil and residual stands can be minimized. Thus the system of centralized processing enters into competition with the harvesters. The woodyard system has to compensate the lower costs and the higher productivity of the harvester system by a higher yield of volume and a higher value through perfect sorting and marketing. In comparison it must be taken into consideration, that woodyard system masters a bigger number of targets.

- Collecting and concentrating of a large volume of timber
- Trimming with stationary technology
- Sorting in a large number of assortments with a high accuracy of measurement
- Marketing adequate to customers wishes
- Computerized management and control of the whole forestry commission by data transmissions of volume and sales

It is the philosophy of the centralized processing to sort every piece of wood including bark and branches in the best way and to deal with a customer defined product.

## CONCEPTS

Up to now no uniform solution has been found. The following types are delivered to woodyards:

- log length
- tree length
- full trees

Full trees are yarded where large volumes of timber are available, where the transport distances are short and it is possible to utilize branches, needles and bark. Tree length are used if delimbing in stands or on forest roads can be mechanized, where several owners deliver the wood and if it must be transported for long distances. Log lengths are seldom delivered to woodyards. Only when a higher value is possible by sorting in different diameter, quality and dimensions (even though crosscutting is already done in the forest) this is of advantage.

## CAPACITIES

Due to the technical development there is an enormous rise in the productivity, the capacity is expanded and the economy improved. The technology of trimming tree length and full trees is young and capable of development. Especially the enormous development of electronics and data processing has had a very positive effect.

In detail the following work steps were improved:

- Automatic measurement of length, diameter and sweep. Moreover first attempts were carried out to measure internal flaw in wood.
- Optimization of sorting.

Compared to human productivity with the help of todays systems the working time could be reduced decisively.

- Automatic, perfect control of the equipment
- working times for crosscutting could be minimized
- transport phases were accelerated
- breakdown time could be reduced
- By using hydraulic loader the transportation and the storage of finished assortments were improved

It is to expect that further improvements are possible in the future. There is no sign that the positive development will end.

## DEVELOPMENT TO A MANAGEMENT SYSTEM

Tracing back to the automatic measurement of number of trees, length, diameter and quality of timber and of the finished assortments a lot of additional targets can be managed by the woodyard thanks to modern data processing.
Data technic includes in varying degrees the timber quantity, the wage of the forest workers, the cost of the truckers, the control of storage quantity, the marketing, accounting, customer files, but especially planning, steering and control in the company. Quick processing of the wood products bring the best results.

## UTILIZATION OF THE SYSTEM BY THE SAWMILL INDUSTRY

Especially larger sawmills are using the system of centralized sorting (both tree length and log length). The system concentrates on automatic measurement of the wood, and the data processing with the aim to optimize saw timber. Here again the data is used for wage calculation, steering and control, purchase and sale of timber.

In summary it is a target of future development to combine the higher output of the one-grip harvester with an optimal product policy, marketing and organization of centralized processing.

# RECOVERY OF FOREST RESIDUES FOR ENERGY IN THE WESTERN UNITED STATES

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## SUMMARY

Recovery of forest residues in the western United States have been hindered by the lack of good markets for the residue products. There have been some active residue recovery operations in parts of the region and demonstration research on a variety of recovery and processing methods in other parts. Recovery methods that bunch trees or residue for skidding and that move the residue and commercial product concurrently have been most effective. Processing options have included the use of whole tree chippers in residues and whole trees, chunkers, grinders and the use of a hydraulic firewood shear. The chippers have not been effective in residue material, but work well in whole trees. The grinders have high investment requirements but are effective in reducing short residue pieces to a uniform size. The firewood shear has worked well in both residue pieces and longer trees.

Keywords: Biomass, Wood Energy, Residue recovery

## INTRODUCTION

Timber harvesting operations in the western United States include both ground based skidding and cable yarding sytems to accomodate the wide range of slopes. Mechanized harvesting systems have become more common with the improving capabilites and slope ranges of feller-bunchers, saw-type cutting heads, and increased mobility in mechanized delimbing and bucking equipment.

Residue recovery operations in the region have included mechanized harvesting and whole tree chipping for wood fuel chips, experiments with residue removal as part of site preparation operations, conversion of stagnant timber stands, and research demonstrations of recovery and processing equipment and systems. An oversupply of mill residues and the lack of good markets for hog fuel have limited commercial applications of many residue recovery systems, however. Research demonstrations have established operational guidelines and cost estimates for feasible systems that could be used when the demand for wood fiber allows a better market for forest residue.

Forest residues in the region include standing trees in dead and stagnant timber stands, material from precommercial thinnings, and residues left after commercial logging. Stagnated, dead and dying trees have excellent potential for recovery when concentrated as part of a stand of timber. The trees are often small and are usually distributed in a narrow range of diameter classes. The uniformity and high concentration levels of the trees allow the use of existing timber harvesting equipment in recovery and processing.

Whole trees cut in thinning activities also have potential for recovery, but are less desirable than material from stagnant stands because the trees are less concentrated. Bunching could be accomplished with mechanized harvesting equipment, but the frame mounted feller-bunchers that work most effectively in thinnings are restricted to areas with moderate slopes. This constraing exclude many timber stands in the region.

Costs associated with recovery of forest residues left after logging are adversely affected by the non-uniformity of material size and the wide distribution of the material across the harvest site. Non-uniformity in material size makes it difficult to match the size and type of equipment to the size characteristics of the material. Selection of small equipment can exclude recovery and processing of large residue pieces. Selection of large equipment will result in underutilization of the equipment when smaller material is handled.

Wide distribution of logging residue across the site makes delivery to the landing quite costly, especially if the recovery method requires individual handling of each piece. The most efficient methods of recovery will be those that include procedures to accumulate or prebunch material in cost effective manner and/or those that incorporate concurrent recovery of the residue material with a primary commercial product.

Two major considerations in planning for any forest residue recovery operation include the investment requirements of the system and potential utilization levels of the equipment. High investment is often associated with the heavy and unique equipment often used in residue processing. Mechanized harvest systems generally rely on sophisticated technology and heavy, unique machines are often needed in the processing step to reduce the residues to a transportable and usable form. High capital investments in a harvest system translate into a need for high production, minimum downtime, few equipment moves, and a long operating season. These four factors cannot always be obtained when dealing with forest residues.

## LONG DISTANCE TRANSPORTATION

Efficient long distance transportation will be one of the keys to the economic recovery of forest residue. The most important variable associated with hauling costs is, of course, hauling distance. Distance takes on extra importance when the material is of low value and low density. The low value associated with most forest residue products translates to a need to transport as much material as possible on each load. Obtaining maximum legal weights may be difficult, however, because of the relativly low bulk densities of most forest residue products.

Larger haul containers such as chip vans are desirable for hauling maximum weight loads of chips or hog fuel, but these vehicles may not be able to negotiate the curves and widths of some logging roads in parts of the western United States. Chip vans often have less clearance and a higher center of gravity than a conventional log truck and trailer and will require wider roads on curves. Figure 1 illustrates the road widths needed to accomodate a truck and trailer on curves of increasing radius. A shorter radius curve represents a tighter curve. The road widths are wider for a truck with chip van than with the conventional log truck used as the design vehicle for many western logging roads. Hauling options that can negotiate most logging roads and that are currently available in the region generally have limited volume capacity for hauling. The volume capacity of the vehicle is reached long before the legal weight capacity.

Although hauling costs increase with distance, the hauling cost rate expressed in dollars per ton-kilometer decreases. At shorter distances, a higher percentage of the cycle time for a truck is spent loading and unloading. Typical hauling rates for the western United States are presented in Figure 2 for four hauling alternatives. The hauling rate curves flatten beyond a one-way haul distance of about 30 kilometers. The rates shown in Figure 2 were determined for a processing rate on a chipper of 14.3 metric dry tons per hour, and travel speeds of 1.4 minutes per kilometer for tractor-trailer combinations and 1.31 minutes per kilometer for dump trucks.

## PROCESSING OF WOOD RESIDUES

The non-uniformity of logging and forest residues dictate some type of process at the landing before long distance transportation of the material. Equipment designed to accomplish this task include chippers, chunkers, shredders, grinders, shears, firewood processors, and balers. Each produces a different product, but the common factor is reduction or consolidation of the material into a uniform size product.

Whole tree chipping is effective when operating in whole trees and when trees are continuously delivered to the infeed area of the chipper by an auxilliary skidding or loading vehicle. Direct delivery of trees to the chipper is generally needed because the loading unit serving the chipper often has limited extension and power. The loader limitations of most chippers will not allow the operator to efficiently retrieve trees from large, tangled decks.

Chipping or chunking will be the most effective processing option in whole trees. All of the other processing alternatives (grinding, shredding, etc) are subject to length limitations on the material being processed. Most whole tree chippers are very inefficient, however, when used to process logging residues of mixed lengths. The non-uniformity of the residue makes

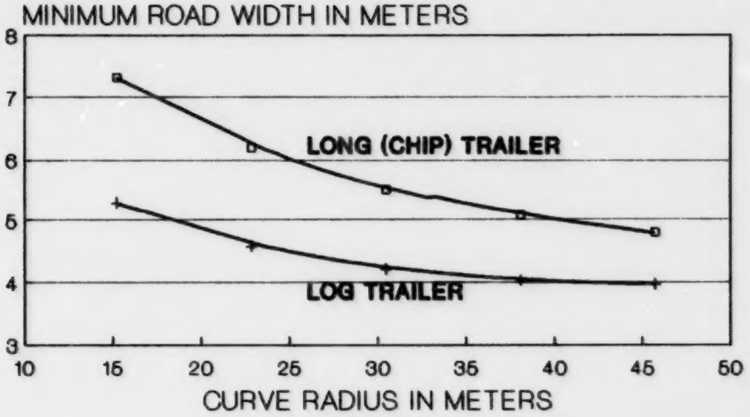

Figure 1: Road widths needed to allow passage of a truck and chip van and a log truck and trailer as a function of the radius of the curve.

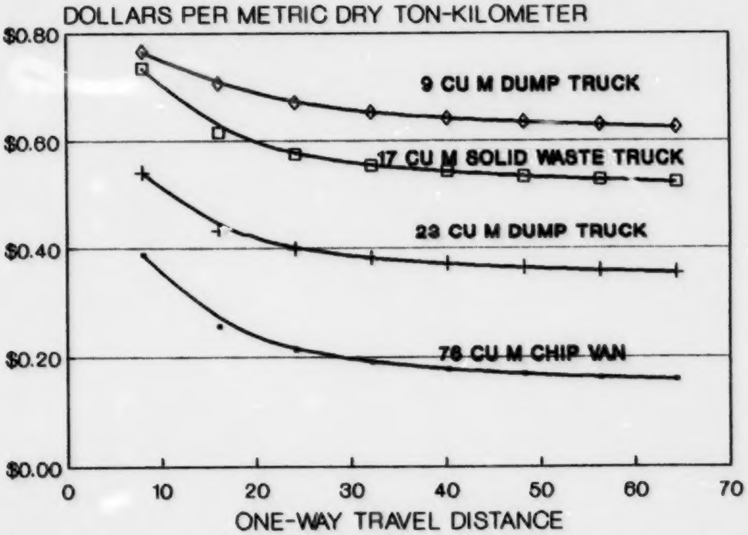

Figure 2: Hauling rates in United States dollars per metric ton-kilometer for four hauling options in the western United States.

the material harder to deck in readily accessible areas. As a result, the chipper operator spends extra time finding and loading pieces for chipping and will probably not be able to sustain continuous chip production. Several studies in the Pacific Northwest have demonstrated this point. Results shown in Figure 3 compare the costs to recover material from stockpiles and chip in residues and whole trees. Effective chipping costs in residues are much higher than in whole trees (Johnson, 1984).

An exception to this general limitation on the use of chippers in residues is a machine designed by Nicholson Manufacturing of Seattle, Washington, specifically for use in wood residues. The chipper consists of a horizontal chipping drum and long feed chain, but requires a separate loader for delivery of the residue to the feed conveyor. The feed chain consists of three sections of drag chain. The action of these chains tends to align the residue as it moves toward the chipping drum. A large feed roller located just before the chipping drum holds the material down on the chain for chipping. The capability of the machine to align and hold several small pieces for chipping makes it effective in processing residue. Investment costs for the chipper and associated loader will be high, however, so operations must be carefully planned to minimize non-productive time.

The inefficiency of chippers in residue is also illustrated with results from a study of chunkwood processing in whole trees and residues. Chunkwood is a unique product under development for several years in the United States and the Scandanavian countries. Processed chunks vary in size with the diameter of the piece being processed and can be chunked to depths of 6 to 11 centimeters. The chunkwood chipper used in the demonstration research experiments was a prototype developed on the chasis of a Morbark Model 18 whole tree chipper. The infeed system was not changed significantly from that of the original chipper.

Figure 4 shows production rates of the chunker when operating in whole trees and residues. The actual rate of chunking is about the same in residues and whole trees. There are significant differences in the production rates, however, when the additional time required to find and load new pieces is included and when all delays are included. In a chipping or chunking operation conducted in whole trees, most of the loading activity occurs while the previous load is processed and doesn't require additional time. When operating in residues, extra time is required to find and load the residue pieces.

High investment requirements for chippers, their limitations in processing logging residue, and a relatively high demand for firewood led to the development of a hydraulic shear that could process residues into 46 to 61 cm lengths of firewood. The mobile shear was built on a surplus military truck to facilitate recovery of logging residues at and near logging roads and landings. The mobility of the shear allowed it to be moved quickly between residue decks. The system required a separate loader to load material on the infeed conveyor. Residue pieces longer than 10 - 12 m were partially supported by the loader until the shearing action could reduce the pieces to a length that could be accommodated by the infeed conveyor.

Demonstration projects conducted with the shear under a variety of residue conditions have shown it to be most effective when operating from

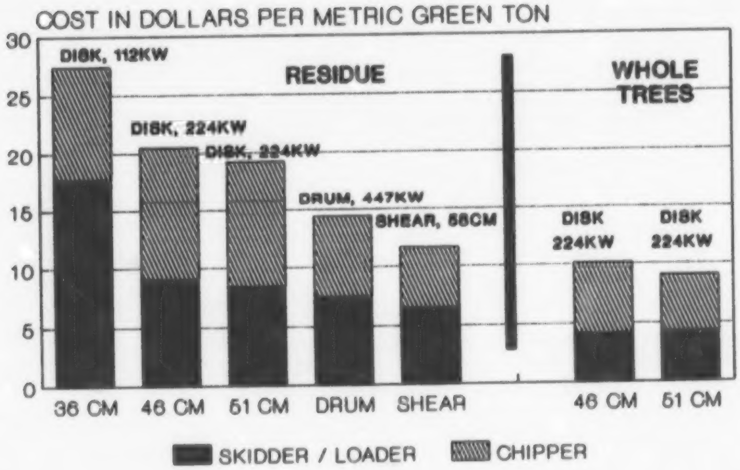

Figure 3: Costs of recovery from stockpiles and chipping residues and whole trees with a variety of whole tree chippers and a hydraulic shear.

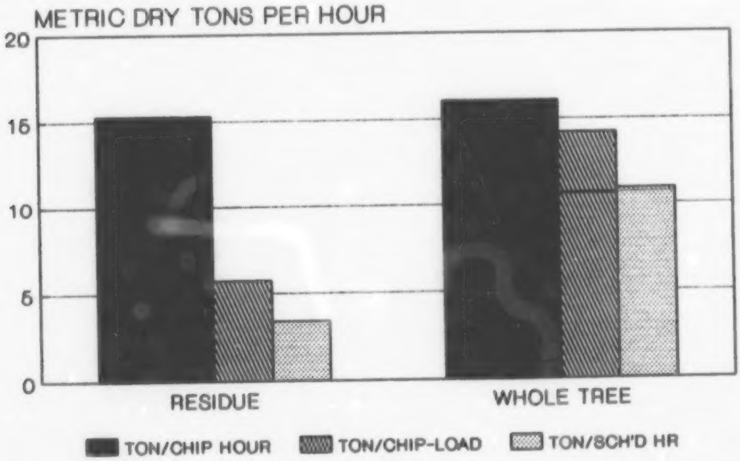

Figure 4: Production of a chunkwood processor when operating in residues and whole trees.

residues that have been pre-decked for processing (Johnson et.al. 1987). Production costs of the shear compare favorably with those of whole tree chippers in residues as shown in Figure 3.

Some commercial grinders and shredders have been used in the region, but a number have been built locally by the firm doing the recovery operation. The general limitations on grinders in this region have been in their lack of mobility and the length requirement for material fed through the grinder. One firm, Hermann Brothers Logging and Construction Company, use a shredder in conjuction with a whole tree recovery operation (Hemphill, 1989; Lambert et.al., 1987). The shredder is part of a system designed to recover multiple products from stagnant stands of small timber. Whole trees are delivered to the landing and are sorted for sawlogs, chippable trees, and non-chippable material. Chippable material is run through a multiple-stem debarker and then through a whole tree chipper to produce clean chips that will meet pulp chip standards. Sawlogs are processed and loaded on a truck. The residuals from debarking and sawlog production and non-chippable materials are fed to the shredder for production of hog fuel.

Baling has been proposed as a means of compacting loose wood residues to increase bulk density and to create modules that can be easily handled, transported, and stored. A variety of compaction devices have been experimented with, ranging from specially designed balers to modified agricultural balers and compactors called "module builders".

Balers have been most effective in small diameter material such as limbs and tops that might be left after pruning or delimbing operations. A baler designed at Virginia Polytechnic Institute and State University, and tested in both the eastern and Pacific northwest regions of the United States, first sheared the residue to length and then compacted and baled the sheared pieces. It produced bales in softwoods with green bulk densities averaging 517 kilogram per cubic meter. Research results from the northwest indicate that smaller diameter material produced a more stable bale and that longer stems provided for a more efficient baling operation (Schiess and Yonaka, 1983).

One system for compaction of wood residues involved modification of a module builder for cotton. Material is loaded into a rectangular metal box and rollers are used to compact layers of the residue. It produces compacted modules of wood residue 9.7 meters in length, 2.2 meters wide, and 2.1 meters high. Bulk densities of the modules in initial tests averaged 192 kilograms per cubic meter. The modules can then be loaded on truck trailers for long distance transportation to a central processing plant (Miles, no date).

The balers and other compacting mechanisms for wood residue are still at the stage of field research. Research prototypes have been constructed and tested, but the machines are generally not commercially available.

The problems caused by landing and access constraints in some parts of the region may limit in-woods processing of whole trees. Several studies (Gonsior and Johnson, 1985; Gonsior, 1986; Keegan et al., 1987) suggest some degree of whole tree hauling to a point where adequate landings exist for processing. Where legal restrictions on length and content of the load can be met and curvature and width of the roads can accommodate overlength loads, hauling of whole trees provides a means for getting most of the commercial and residue components to a point of processing or end use without the problems associated with in-woods sorting and processing. Loading and hauling costs would increase over those incurred with log length material. Total costs would probably be comparable with those of in-woods processing, but the system would not involve as many risks with underutilization of equipment. Keegan, et. al. (1987) suggest that the method would only be feasible on trees with diameters less than 36 centimeters, primarily because of length limitations on the whole tree loads, and because the material would probably be felled and bunched with feller bunchers.

## DELIVERY OF WOOD RESIDUES TO THE LANDING

The percent ground slope in the recovery area determines whether ground based skidding or cable yarding systems are used to move the residue to the landing. The transition from ground based to cable ground occurs in the range of 35 - 50 percent ground slope. The specific transition point within this range will vary with the landowner, the type of soils on the site, and the location of the access roads. Costs and constraints on residue recovery increase substantially as operations move from gentle to steep terrain.

Operations in steep terrain of the western region of the United States face constraints caused by limited landings and poor access. The capabilities of the yarder for decking logs away from the yarding corridor or the presence of an auxilliary landing machine such as a skidder or loader to move yarded material away will be important when landing areas are limited. The yarding corridor must be kept free of trees, especially if the trees require some type of landing process. The landing area can be easily congested, especially when sawlogs and a residue product are moved concurrently to the landing.

On gentle slopes, recovery of the entire tree as a residue product will usually result in the lowest recovery and processing costs since equipment currently available for mechanized harvesting operations can be efficiently used. Recovery of forest residues after a first entry for the primary commercial product, however, will be adversely affected by the non-uniform size of the residual material, low density of the material per acre, and a general mismatch between equipment and piece size. Since the residue is generally broken and scattered across the site, conventional skidding and yarding equipment is often underutilized, especially when the recovery operation requires hooking of each piece. It takes many pieces to make a full load, but the number of chokers that can be realistically hooked on one turn are limited. Limitation of machine loads by the number of chokers means the equipment will seldom be loaded to maximum weight capacity (Johnson et.al, 1987).

Cost comparisons of the skidding and yarding costs of several residue recovery operations are shown in Figure 5. The cable systems were generally more expensive than ground-based systems. Costs for both cable and ground based operations were lower, however, when the residue was removed concurrently with the commercial product. Some of this cost benefit can be lost, however, if the material handling system at the landing does not keep the landing area clear of congestion. In most concurrent recovery operations, it was necessary to remove at least one of the products from the site

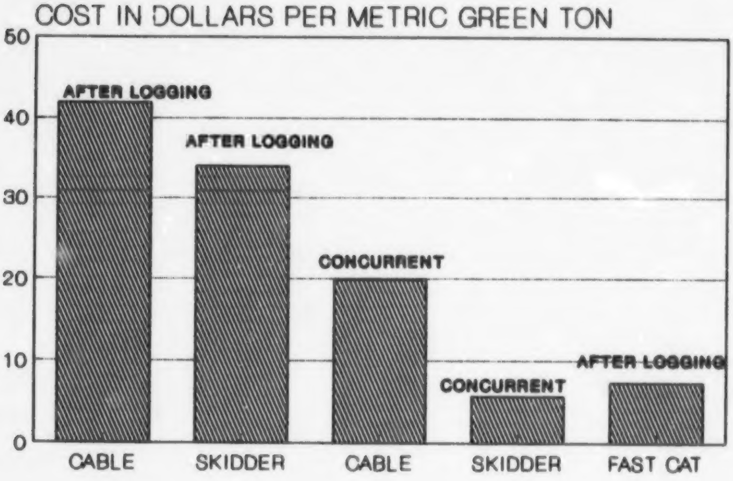

Figure 5: Comparison of skidding and yarding costs when delivering residue to a landing.

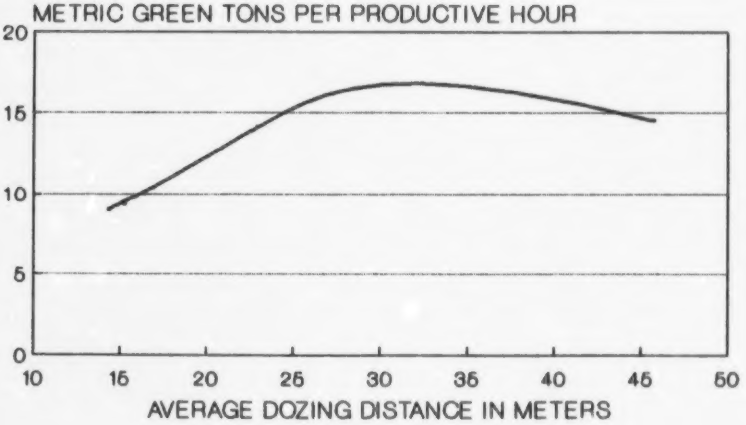

Figure 6: Production rates in metric tons per hour for dozing to roadside as a function of dozing distance.

concurrently with the skidding operation. This implies hot processing of either the sawlog or residue product.

One variation to systems requiring the hooking and unhooking of each residue piece utilized modified fast track skidders such as those manufactured by FMC Corporation. The machines were modified to include a dump box and loading grapple. The equipment was used by a firm specializing in site preparation and fire control on public and private lands. The firm contracted to dispose of the logging residue and prepare the site for planting. In the process they would recover the some of the residue for hog fuel. Residue was concentrated on the site with a separate hydraulic loader. The modified skidders were then loaded with the sorted residue and the residue was transported it to a landing area. Material was stockpiled for chipping with the Nicholson Fuelwood Processor. Transport of the material in dump boxes kept it clean and allowed relatively efficient handling of the shorter pieces. Delivery costs of the modified FMC's were shown with costs of other recovery options in Figure 5 (Johnson,1984).

Another variation in moving residues on gentle terrain involved modification of the dozer piling technique sometimes used to dispose of wood residue on harvest sites. Dozer piling usually involves piling of material at random points across the site for burning. Modification of this technique to push the material to an access road was used to concentrate the residue at roadside for processing. A research demonstration with this concept involved a range of dozing distances from 30 to 91 meters. Hours per hectare increased with dozing distance, but the production rate in metric dry tons per hour reached an optimum at about 60 meters as shown in Figure 6.

Costs of moving the material to roadside with dozers were much lower than comparable costs of moving the logging residue with skidders. Piles created in this operation were quite tangled, however, and required a subsequent handling step before the material could be processed into chunkwood. This sorting and piling step was done in one instance with a long boom crane and added substantially to the cost of the material. Subsequent analysis has shown that the extra handling step would have been more effectively done with a grapple skidder.

Concurrent recovery of residue and the normal commercial product will generally be less expensive than separate recovery of the residue. This type of recovery operation is not always possible, however. An alternative may lie in a designed two stage harvest operation. The concept involves recovery of the largest sizes of the primary commercial product on one entry and recovery of the smaller commercial pieces and residue on a second entry. This allows concentration of most of the residue material in a planned felling operation and provides for a better match of equipment and piece size. Goetz and others (1987) pioneered efforts at intense utilization of forest biomass on gentle slopes by making multiple entries into the stand. They used a sequence that removed the smaller material first. Brown and Associates (1983) evaluated double entry logging with cable yarders in southwest Oregon. They also concluded that it was more efficient to remove the small material first. Taking smaller material on the first entry clears the stand of small timber and debris so the larger, more expensive equipment can be more productive when removing the larger trees. Removal of the smaller material involves concurrent recovery of the smaller sawlogs or pulpwood pieces and the residue product. Less landing congestion is involved than with other concurrent recovery operations because the larger logs do not have to be handled at thattime. One disadvantage is that the residue associated with the large trees is not recovered.

Johnson and Castenada (1984) also conducted a double entry logging project, but conducted the project in smaller timber and on steep terrain. Their project concluded that the concept had potential when there is a viable market for the wood residue product and a wide range in sizes of the material that must be handled. A wide range of material size provides the best opportunity to match equipment and piece size. When the size differential is small, the costs associated with an extra entry of equipment cannot be offset by gains in better equipment utilization.

## SUMMARY

Residue recovery operations in the western United States have been hindered by the lack of consistent demand for a residue product. The current supply of mill residuals is adequate for the current demand for hog fuel. Concerns over future supplies of wood fiber to area mills and over the environmental impacts of current residue disposal methods could provide incentives and markets for more residue recovery from the woods, however. When that happens, residue recovery operations are likely to focus on recovery methods that involve concurrent removal of the primary and residue product and processors that can handle variation in the length and diameter of the material.

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# MECHANIZED HARVESTING ON STEEP TERRAIN IN THE PACIFIC NORTHWEST

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## SUMMARY

Significant changes are occurring in the Pacific Northwest logging environment. One important reason for change in the logging practices is a gradual but steady transition from large, old growth timber to much smaller second growth trees. With smaller and more nearly uniform stem sizes, opportunities for logging mechanization have increased. In addition to a shift toward harvesting smaller trees, the labor force and safety issues are other important driving forces affecting further mechanized logging methods. Skilled workers interested in logging are becoming more scarce. Logging continues to be one of the nations most dangerous occupations with many accidents occurring to persons working on the ground performing activities such as manual felling, limbing, bucking and chokersetting. Workers' compensation insurance rates are a large portion of current logging costs on non-mechanized operations.

Cable logging is the prevalent yarding method in the mountainous terrain of the Pacific Northwest. Currently, approximately 75 percent of timber harvesting in the region is done with cable systems. Tress are manually felled and processed prior to log length yarding to the landing. Harvesting studies have shown that manual limbing and bucking are very time consuming and many chainsaw accidents occur while completing this work. As an alternative, the Forest Engineering Department at Oregon State University has completed several studies on a different wood handling system: 1) manual felling, 2) whole tree yarding to the landing and 3) mechanical processing of the trees on the landing with a stroke boom delimber.

A key factor in mechanized harvesting is production balance between the different components of the system. Delimber utilization rates varied from 42 percent to 83 percent. Factors that contribute to system balance and delimber utilization on a cable yarding operation with mechanical processing at the landing include: 1) yarding productivity and delays, 2) equipment arrangement on the landing, 3) landing size and 4) delimbing boom design. Relatively low yarding production rates compared to a high delimber production capability limit utilization of the delimber and thus the whole system. There are opportunities and some experience with new methods to increase cable yarding production by yarding bunched trees that are felled and placed in piles by a steep slope self-leveling feller buncher.

# WOOD FUELS' TENDENCY TO BRIDGE OVER OPENINGS

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## SUMMARY

Operational problems in energy plants using wood fuel are usually related to internal handling of the fuel. One common problem is the fuel forming bridges over openings. This is a classical problem in handling particulate solids. However, established theories for predicting bridging are not applicable on wood fuels. Therefore relations were established between wood fuels tendency to bridge and traditional properties such as moisture content, particle shape, size and size distribution.

The tendency to bridge was measured as the critical opening needed to avoid a bridge to be formed. Sawdust, fuel pellets, fuel chips, hogged fuel and chunkwood, in total sixteen different wood fuels, were studied.

Bridging tendency varied considerably among the tested fuels. An increasing tendency to bridge was the result of increasing values of the three factors: content of hooked or long and thin particles, fuel bed depth over the opening, and moisture content of the fuel. When the content of hooked or long and thin particles was low, the fuel bed depth and the moisture content had little influence on the bringing tendency. The results indicate that more attention should be paid to the particle shape and the content of particles known to cause problems.

Keywords: Wood fuels, handling characteristics, arching, moisture.

## INTRODUCTION

Mankind have used wood for heating and cooking since the dawn of time. For half of the earths population wood is still the main energy source. Wood fuel has also for a long time been used by wood industries and during the latest decades by heating plants.

Large scale use of wood fuel includes internal transport of the fuel from the point of delivery to the combustion chamber. Inventories have shown that most operational problems in plants using wood fuels are related to internal handling and the quality of the fuel (ETU, 1985; Leighton, 1981; Levelton, 1982). One common problem is the tendency of some fuels to form bridges over outlet openings even if the single fuel particles are smaller than the opening. In spite of a long tradition in wood industries to handle wood fuels, little is known about their basic handling characteristics and their relation to fuel particle shape, size, size distribution, moisture content etc.

Established methods for predicting a bulk solids tendency to bridge are based on theories first developed by Jenike (1961 and 1964). They assume the bulk solid to be a homogeneous and isotropic continuum and fully plastic (Enstad, 1981). This means that the particles should be small compared to openings, not irregular in shape and the fuel should not be elastic. These assumptions are not valid for wood fuels. Consequently the established methods for predicting a particulate solids tendency to bridge are not applicable on wood fuels.

The aim of ongoing research at the Swedish University of Agricultural Sciences in Garpenberg is to establish relations between basic handling characteristics and traditional wood fuel properties such as moisture content, particle shape, size and size distribution.

This paper will summarize and discuss studies of sixteen different wood fuels tendency to bridge. More details are given by Mattsson (1989).

## MATERIAL AND METHODS

### Material

The tendency to bridge was measured for different kinds of chunkwood made of birch, spruce and salix, hogged fuel from spruce branches, fuel chips of birch, sawdust of softwood and fuel pellets, in total sixteen fuels with a particle length from 2 to 180 mm (see table 1).

Some of the fuels, sawdust and fuel chips, represent materials with relatively well-known handling characteristics. They have been used at saw mills, pulp mills or heating plants for many years. Fuel pellets have size, shape, density and other properties in common with fodder pellets which have well-known handling characteristics.

Chunkwood is a new fuel and was produced using two different machines. The double-disc wood chunker, jointly developed in Garpenberg by US Forest Service and Swedish University of Agricultural Sciences (the Garp-chunker), is further described by Arola (1985). It cuts the raw material with two counter-rotating curved knives. The conescrew chipper (Sasmo HP-30), developed in Finland and further described by Nurmi (1986), cuts the raw material with a sharp conical screw.

For each fuel the following properties were measured: size (length of predominant particles), size distribution, shape of predominant particles, content of abnormal particles and moisture content. The bulk density was not measured since it is nearly the same for different wood fuels (with the same moisture content), except for compacted fuels such as fuel pellets.

The particle size distribution was measured by a shaking screen and is presented in figure 1. The shape of predominant particles was described as the "shape ratio" (length/thickness of normal pieces). The content of abnormal particles with a shape known to affect the handling characteristics was described as "proportion of hooked or long and thin particles" (the number of this kind of particles divided by the total number of particles, excluding fines). "Hooked" was defined as particles with a hook that allows particles to interlock. "Long" was defined as more than twice the length of normal (predominant) particles (see table 1). Hog fuel had a much higher shape ratio than the other fuels. Hog fuel and chunkwood made of undelimbed trees had a higher proportion of hooked or long and thin particles.

The moisture content was varied from 10 to 60% (green basis). Fuel pellets were only tested at 15% which is a normal moisture content at delivery.

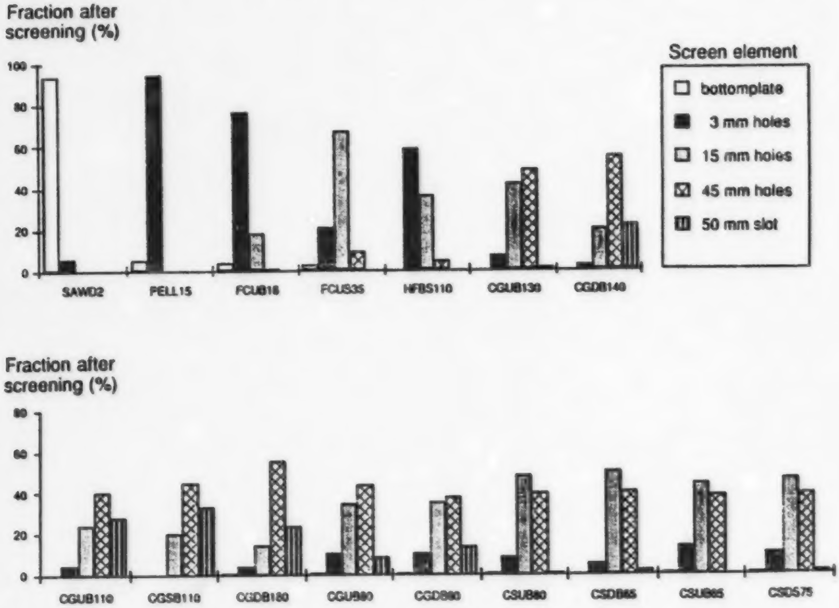

*Figure 1.* **Particle size distribution (mass-percentage) in the fuels studied. (For abbreviations, see table 1).**

**Table 1**. *Description of the wood fuels studied.*

| Abbr. | Kind of fuel | Preparation | Raw material | Particle length (mm) | Shape ratio [a] | Hooks & long parts [b] (%) |
|---|---|---|---|---|---|---|
| SAWD2 | **SAW**Dust | saw mill | softwoods | 2 | 3.5 | 0.6 |
| PELL15 | **PEL**Lets | pelletizer | sawdust, bark | 15 | 1.8 | 0.9 |
| FCUB16 | **F**uel chips | disc Chipper | Undelimbed Birch | 16 | 5.4 | 1.0 |
| FCUB35 | -"- | " " | -"- | 35 | 3.2 | 8.8 |
| HFBS110 | **H**og **F**uel | hammer mill | Branches, Spruce | 110 | 35.0 | 30.6 |
| CGUB130 | Chunkwood | Garp-chunker | Undelimbed Birch | 130 | 8.5 | 31.5 |
| CGDB140 | " | (double-disc | Delimbed Birch | 140 | 7.0 | 1.3 |
| CGUB110 | " | chunker) | Undelimbed Birch | 110 | 4.5 | 22.1 |
| CGSB110 | " | " | CGUB110 Screened | 110 | 4.5 | 1.5 |
| CGDB180 | " | " | Delimbed Birch | 180 | 4.5 | 6.9 |
| CGUB80 | " | " | Undelimbed Birch | 80 | 4.0 | 20.2 |
| CGDB80 | " | " | Delimbed Birch | 80 | 4.0 | 0.7 |
| CSUB80 | " | Sasmo HP-30 | Undelimbed Birch | 80 | 6.7 | 15.1 |
| CSDB65 | " | (conescrew | Delimbed Birch | 65 | 6.5 | 2.9 |
| CSUS65 | " | chipper) | Undelimbed Spruce | 65 | 5.4 | 26.1 |
| CSDS75 | " | " | Delimbed Salix | 75 | 5.0 | 1.7 |

[a] Shape ratio = length/thickness of normal (predominant) particles
[b] Proportion of hooked or long and thin particles

## Methods

As mentioned above established methods for predicting bridging in bulk solids are not suitable for wood fuels. Instead the critical opening needed to avoid briding was measured directly (see figure 2). The fuel, 0.55, 1.1 or 1.65 m$^3$ depending on bed depth, was poured into a box with an outlet opening in the bottom and leveled to the desired bed depth. When the bottom was opened the fuel formed a bridge over the opening. The opening slot was slowly increased until the bridge was broken and the slot width was measured. This critical opening width is a measure of the bridging tendency of the fuel. Eckhoff and Leversen (1974) have used the critical opening width as a measure of bridging in a similar way. After measuring, the box was emptied and the procedure repeated. Measurements were made at 500 mm bed depth for all fuels and at 250 and/or 750 mm for nine of the fuels. Ten or fifteen measurements were made for each combination of fuel, bed depth and moisture content.

This method does not give absolute figures on bridging but makes it possible to compare known fuels such as sawdust, fuel pellets, fuel chips and hogged fuel, with less known fuels. The procedure is further described by Mattsson (1989).

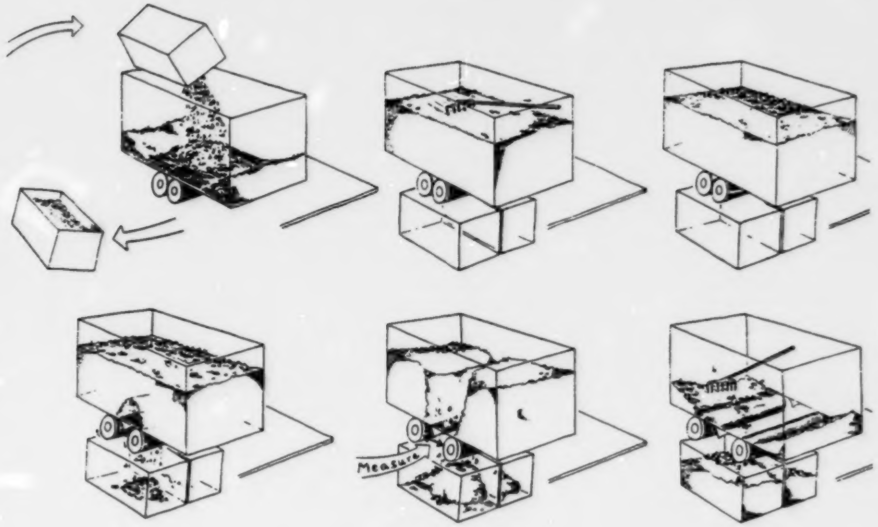

*Figure* 2. **Method for measuring the tendency to bridge in wood fuels.**

## RESULTS AND DISCUSSION

There was a great difference among the fuels in their tendency to bridge. The critical opening width varied from below 30 to over 1000 mm depending on fuel, moisture content and bed depth. An analysis of variance (ANOVA) with Duncan's multiple range test was made for bridging means for the different fuels at 500 mm bed depth (SAS Institute Inc., 1985) (table 2). Duncan's multiple range test is a powerful and widely used method for detecting differences between means (Montgomery, 1983).

Chunkwood made from undelimbed trees by the conescrew chipper has means around 700 mm, significantly higher than other fuels. The six fuels with the highest bridging value are all made of undelimbed trees or branches and have a high proportion of hooked or long and thin particles. Chunkwood from delimbed trees and screened/sorted chunkwood have means from 160 to 290 mm, significantly lower than those from undelimbed trees. Screening and sorting chunkwood made of undelimbed birch decreased the mean bridging value from 369 mm (CGUB110) to 184 mm (CGSB110). For the same kind of raw material, chunkwood made by the conescrew chipper gives higher values than chunkwood made by the double-disc chunker.

**Table 2.** *ANOVA for means of bridging (mm) at 500 mm bed depth.*

| Abbr. | Kind of fuel | | Mean (mm) | N [a] | Duncan grouping [b] |
|---|---|---|---|---|---|
| CSUB80 | chunkwood | conescrew chipper | 717 | 20 | A |
| CSUS65 | " | " | 684 | 20 | A |
| HFBS110 | hogged fuel | hammer mill | 574 | 75 | B |
| CGUB130 | chunkwood | double-disc chunker | 500 | 60 | C |
| CGUB110 | " | " | 369 | 30 | D |
| CGUB80 | " | " | 364 | 20 | D |
| CGDB140 | " | " | 289 | 40 | E |
| CSDS75 | " | conescrew chipper | 234 | 20 | F |
| CSDB65 | " | " | 211 | 20 | F G |
| CGDB180 | " | double-disc chunker | 207 | 45 | F G H |
| CGSB110 | " | screened/sorted | 184 | 45 | G H |
| CGDB80 | " | double-disc chunker | 161 | 20 | H |
| FCUB35 | fuel chips | drum chipper | 108 | 40 | I |
| FCUB16 | -"- | disc " | 96 | 20 | I |
| SAWD2 | sawdust | saw mill | 91 | 75 | I |
| PELL15 | fuel pellets | pelletizer | 30 | 15 | J |

[a] Number of observations in the subgroup
[b] Means with the same letter are not significantly (95%) different

Sawdust and fuel chips from undelimbed birch, with a low proportion of hooked or long and thin particles, have means around 100 mm, significantly lower than all kinds of chunkwood. Fuel pellets have a significantly lower mean than all other fuels, 30 mm, probably partly because they were only measured at low moisture content. Sawdust also had low values at low moisture content.

Chunkwood from delimbed trees does not differ too much from fuel chips with respect to bridging. Dry chunkwood from undelimbed birch made by the double-disc chunker has nearly as low a tendency to bridge as chunkwood from delimbed trees, but when the moisture content increases, bridging increases considerably. Chunkwood from undelimbed trees made by the conescrew chipper has the highest bridging values and also high values on shape ratio and proportion of hooked or long and thin particles.

Fuels with a particle length from 2 to 35 mm all had a low tendency to bridge (Duncan group I and J, table 2). However, for the other fuels there was no simple relation between particle length and tendency to bridge. It is obvious that bridging is more affected by other factors.

The tendency to bridge increased when moisture content increased. The effect on bridging, when moisture content was increased, was higher for fuels with high values on shape ratio and proportion of hooked or long and thin particles. This is shown in figure 3 where bridging is plotted versus (moisture content green basis) · (proportion of hooked or long and thin particles). Only chunkwoods from undelimbed birch and spruce (CSUB80 and CSUS65), with high shape ratio, have notably higher values than other fuels.

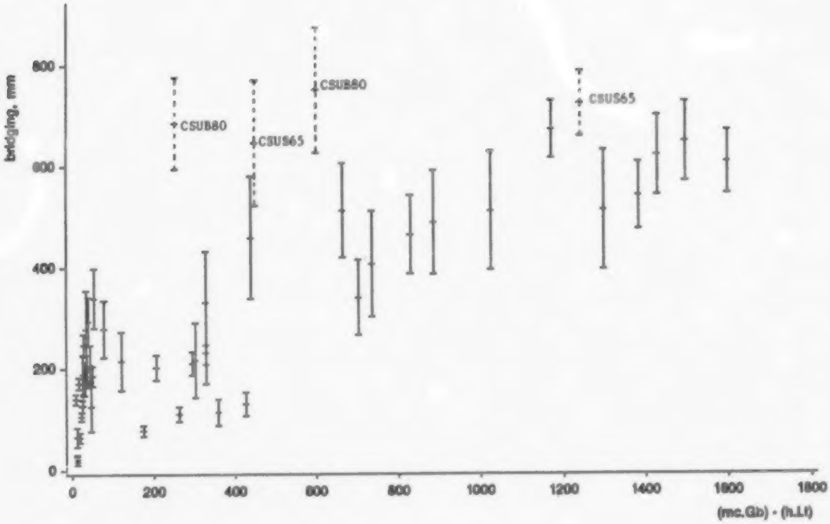

*Figure 3.* **Bridging versus (moisture content green basis) · (proportion of hooked or long and thin particles).**

The effect of changing bed depth is shown in figure 4 for chunkwood made of delimbed and undelimbed birch respectively. As expected, the bridging increased when the bed depth increased, but very little in the case of chunkwood made of delimbed trees. Again the effect was more marked the higher the moisture content and the proportion of hooked or long and thin particles.

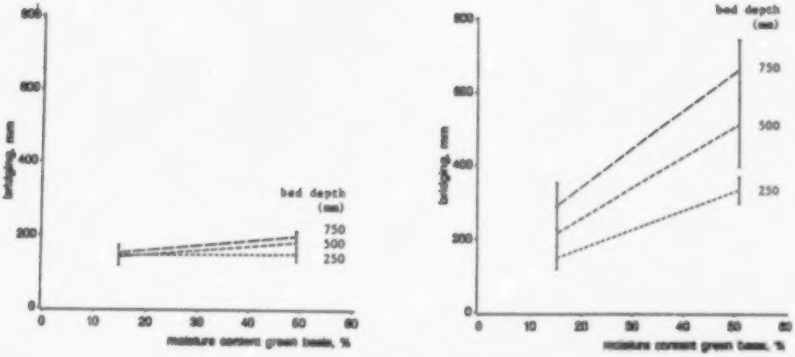

*Figure 4*. **Bridging versus moisture content for delimbed (to the left) and undelimbed chunkwood at three levels of bed depth.**

It is clear that the tendency to bridge is a combined effect of factors such as bed depth, moisture content and particle shape. To test this, a multiple regression analysis was made on the 985 observations of bridging where bridging (B) was assumed to be a function of (h.l.t), (b.d), (mc.Gb), (s.r), (p.l), (h45mm), (s50mm) and (h15mm), alone or in combinations.

(h.l.t) = proportion of hooked or long and thin particles (%)
(b.d) = bed depth (mm)
(mc.Gb) = moisture content green basis (%)
(s.r) = shape ratio (particle length/particle thickness)
(p.l) = particle length (mm)
(s50mm) = particles retained on screen with 50 mm slot width (%)
(h45mm) = particles retained on screen with 45 mm holes (%)
(h15mm) = particles retained on screen with 15 mm holes (%)

The relation

$$\begin{aligned} \mathbf{B} = {} & 54.4 + 0.0356 \cdot (\mathrm{h.l.t}) \cdot (\mathrm{b.d}) + 9.9 \cdot (\mathrm{h45mm}) + 3.24 \cdot 10^{-4} \cdot (\mathrm{h.l.t}) \cdot (\mathrm{b.d}) \cdot (\mathrm{mc.Gb}) \\ & - 2.95 \cdot (\mathrm{s50mm}) - 1.93 \cdot (\mathrm{h15mm}) - 11.1 \cdot (\mathrm{h.l.t}) + 12.4 \cdot (\mathrm{s.r}) - 2.52 \cdot (\mathrm{p.l}) \end{aligned}$$

explains 72% of the variation in bridging. The constant and all coefficients are significant (99.99%). The variable (h.l.t) · (b.d) alone explains 57% of the variation in bridging value (B).

Mean values for bridging are discussed in this paper. For practical considerations the "minimum" opening width needed to avoid bridging is more interesting. The mean plus the standard deviation give a value at which the probability is 84% (in the observations) that no bridging will occur. Means and standard deviations are given by Mattsson (1989). In general the standard deviation was greater the higher the mean.

Published results from other studies confirm that the particle shape influences the tendency to bridge (Bundalli & Martinez, 1982; Jenike, 1961; Levelton, 1982). However, no publication was found where a relation between particle shape and bridging was derived. Fuels are classified in terms of "flowing", "sluggish" or "very sluggish" (Levelton, 1982).

Diverging opinions are noted in published results as to the influence of a change in moisture content. Some claim that the tendency to bridge decreases when the moisture content increases (Bundalli & Martinez, 1982; Mazarskij, 1970). Others have come to the same conclusion as in this study: the tendency to bridge increases when the moisture content increases (Levelton, 1982; Shemsanga et al., 1983). Chang et al. (1983) found the same for corn. The first opinion is based on mathematical models (derived for other materials than comminuted wood) and the latter (confirmed in this study) is based on observations. The mathematical models are based on assumptions with regard to the material which are not valid for wood fuels. Therefore, observations seem to be more reliable for wood fuels than the mathematical models.

## CONCLUSIONS

The tendency to bridge over outlet openings, measured as the slot opening needed to break the bridge, varied considerably depending on bed depth, moisture content, particle shape and the proportion of hooked or long and thin particles. When the bed depth was 500 mm, this bridging value varied from 30 mm for fuel pellets to over 650 mm for hogged fuel and chunkwood of undelimbed trees made by the conescrew chipper. Sawdust, fuel chips and chunkwood from delimbed trees had low values on bridging. Decreasing the proportion of hooked or long and thin particles by screening chunkwood from undelimbed trees, decreased the bridging value considerably.

High bridging values were to a large extent a combined effect of high values on moisture content, bed depth and the proportion of hooked or long and thin particles. The last two variables when multiplied explained 57% of the variation in opening needed to break the bridge, i.e. the bridging value. Adding variables for moisture content, size distribution, shape ratio and particle length, gives a relation that explains 72% of the variation in bridging.

Abnormally shaped particles were found to be of significant importance. A general conclusion can be drawn: more attention should be paid to the particle shape and the content of long and hook-shaped particles. How should these properties be measured? How should comminution equipment be designed to avoid long and hook-shaped particles? How should equipment for internal handling be designed to decrease problems with fuels with a high content of hooked or long and thin particles?

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# LEGGED VEHICLE FOR FOREST OPERATIONS

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FDC: 377.9: (23)

## SUMMARY

A vehicle with a legging mechanism for use as a carrier for forest machines was studied to obtain good trafficability on off-the-road rough terrain and to obtain good stability on steep slopes while aiming for efficiency and safety in silvicultural operations. Energy consumption of the legging mechanisms is discussed, and it is made clear that the most efficient gaits were the larger stances on the steeper slopes. Leg style was determined to be the pantograph style from aspects of energy consumption and the simplicity of the mechanism and its control. The number of legs was determined to be six from the complexity of their control and stability. The control system was studied to obtain suitable gaits for the legged machine under various terrain conditions. The gaits were suitably programmed with micro Central Processing Unit (CPU) devices and controlled with interfacing devices.

Keywords: Forest operations, rough terrain, legged vehicle

## INTRODUCTION

Forestry operations in mountainous areas need much more energy than those in smooth terrain areas. In logging operations, heavy timbers are transported certain distances which consume much energy, and it increases much when the terrain is rough and of great relief energy. Forestry deals with vast areas so that the efficiency of the forest operations depend, in some aspects, on how one can move over the ground. Very steep mountainous forests, such as those in japan, seldom permit a vehicle-type machine to run into the forest and access to a working site directly. However the logging operations overcome rough terrain with cable skyline machines and techniques, and in rather level areas large vehicle-type multi-function machines were introduced recently. Operational efficiency increased by mechanization of the logging operations as stated above. On the contrary, efficiency of operations in silvicultural work is very much the same as in the 1960's. There have occurred no major changes in the methods of work, which are usually manual operations. Silvicultural operation systems based on vehicle operations were established and have been continued experimentally in level areas; namely, line-thinning operations on the national forests in Hokkaido, the northernmost island of Japan. But on rough terrain, which is almost all of Japan, manual operations have been the only method to do silvicultural work.

The supply of forestry labor decreases rapidly without entering younger generations into the forestry work force. The average age of labor increases and this does not result in efficiency of operations and the accomplishment of silvicultural treatments for Japanese artificial forests. We have vast young forest stands growing without suitable thinning treatments.

We need to improve of silvicultural operations, especially in rough terrain areas. It is clear that the mechanization of operations is essential for a good operational environment, ease of work, great safety, and great efficiency. How a vehicle can be introduced into a rough-terrain area, is the greatest problem. We think that a legging mechanisms for a vehicle carrier gives a solution to the problem.

## LEGGED MECHANISM AND THE ENERGY CONSUMPTION

Vehicle-type machines had been used widely for logging operations on flat and smooth terrain. Operational efficiency of vehicular machines usually is greater than that of cable-operation systems because of them requiring less subsidiary works, and many efforts have been made to improve trafficability of vehicles on steep and rough terrain to make for more efficiency. Vehicles with leg mechanisms are one of these contributors. Some machines with such mechanisms already are on sale by some manufactures in Europe and North America[2].

A legged vehicle has the following advantages; namely 1) good stability on steep slopes which is endowed to the machine as it is equipped to position its variable legs, 2) good trafficability on rough terrain because of its walking as if to sample suitable points on the ground, and 3) less disturbance to the ground because of the walking mechanism which goes on supporting the vehicle body by its legs while the vehicle body continues on its way at any time because of moving inertia and driving forces.

Mechanisms for legged vehicle have been made following by observations of animals[3]. Beasts and insects offered good model for legged mechanisms. Beetle and reptile-type legs with a low body and a wide side-extending leg mechanism were analyzed and found to offer a great efficiency in walking. However, vehicular machines for forestry generally were heavy because of the rugged structure of the bodies and equipment, and this required the carrier to bear heavy loads. Legged mechanisms for the heavy structures would be of vertical straightening-styles, and this would make it easy to move through the narrow spaces between standing trees in a forest.

Here we used two patterns of vertical straightening-style legs with both composed of a thigh and a lower leg. One is the man-type whose leg bends forward in the advancing direction, and the other is the bird-type whose leg bends backward from the advancing direction. We assumed the leg mechanisms as shown in Figure 1 which are double pendulums with the same sized thigh and lower leg[7]).

When one moves on a slope, there should be a difference in energy consumption between which way it moves, and it results from the gaits of walking for the legged mechanisms. Suitable gaits for terrain conditions are needed for legged vehicles. The gait is defined by the duty factor $\beta$ which is the ratio of time while a leg is in the supporting mode in one walking cycle. Here assume 0.75 for $\beta$ and the number of legs as four. The vehicle with four legs can walk statically with gaits whose $\beta$ is up to 0.75.

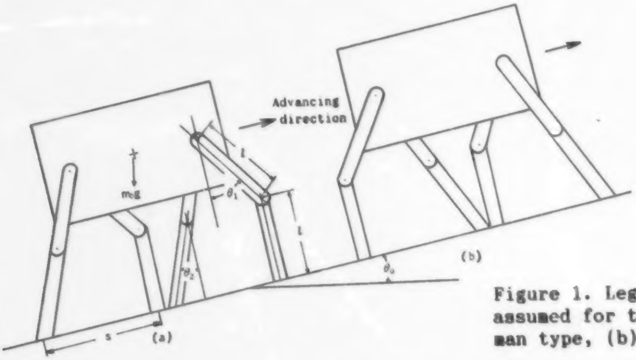


Figure 1. Legs which were assumed for this study; (a) man type, (b) bird type.

The energy required for one cycle of leg movement for walk E is represented by following equation:

$$E = n\ (\ T'\cdot\int_0^1 P'(t_0)dt_0\ +\ T''\cdot\int_0^1 P''(t_0)dt_0\ ), \tag{1}$$

where $t_0$ equals to $t/T'$ when the leg is in a free mode, and $t_0$ equals to $t/T''$ when the leg is in the supporting mode. The leg in a free mode does not support the vehicle, and no load is on the leg. The leg in the supporting mode supports the vehicle, and the vehicle weight is on the leg. T' is the time while the leg is in the free mode, and T" is the time while the leg is in the supporting mode. $P'(t_0)$ and $P''(t_0)$ are:

$$P'(t_0) = \delta\,[M_1'(t_0)\cdot\dot{\theta}\,(t_0)] + \delta\,[M_2'(t_0)\cdot\dot{\theta}_2(t_0)] \tag{2}$$

and

$$P''(t_0) = \delta\,[M_1''(t_0)\cdot\dot{\theta}\,(t_0)] + \delta\,[M_2''(t_0)\cdot\dot{\theta}_2(t_0)], \tag{3}$$

respectively. $\delta\,[x]$ is zero when x is zero and negative, and is x when x is positive. $M_1'$ and $M_2'$ and $M_1''$ and $M_2''$ are the values of $M_1$ and $M_2$ for free mode and supporting mode, respectively. $M_1$ and $M_2$ are i = 1 and 2, respectively, for the following Lagrange's equation of kinetics:

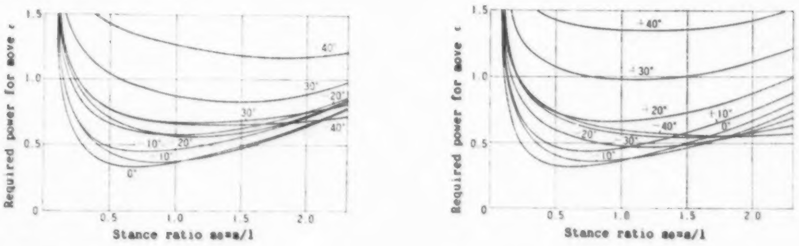
$$M_i = \frac{d}{dt}\left(\frac{\partial E_k}{\partial \theta_i}\right) - \frac{\partial E_k}{\partial \theta_i} + \frac{\partial E_p}{\partial \theta_i}\ . \tag{4}$$

The efficiency of walking can be calculated by the following $\varepsilon$ :

$$\varepsilon = \frac{E}{W \cdot L}, \tag{5}$$

where E is the energy consumed, W is the weight which had been moved, and L is the distance moved.

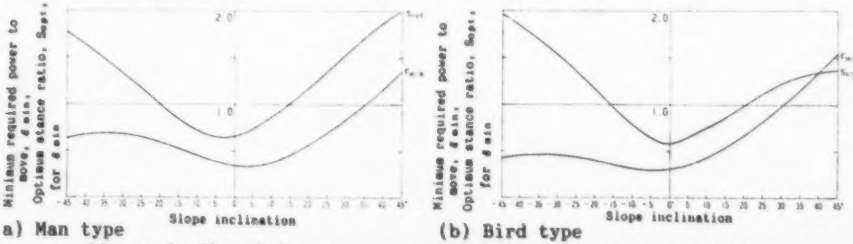
Walking gaits are varied by the stance ratio so, which is the ratio of one stance, s, for the length of the thigh and the lower leg, l, so = s / l. The value of $\varepsilon$ was estimated for various stance ratios for degrees of slope as can be seen in Figure 2. On level ground, the most efficient gait was at the stance ratio of about 0.7 for both man- and bird-type legs. The man-type leg mechanism had a gradually growing tendency for $\varepsilon$ with increasing slope inclinations from an even level. Meanwhile the bird-type leg mechanism needed little energy for advancing negative inclinations when the stance ratio was large. The minimum energy consumption was found for all degrees of slope for certain stance ratios.



(a) Man type (b) Bird type

Figure 2. Stance ratios and the power needed to walk on slopes.

The relationships between the stance ratios for the minimum energy consumptions and the degrees of slope are shown in Figure 3. For both man- and bird-types, leg mechanisms needed minimum power for larger stances at the greater degrees of slope. It was made clear that the walking gait with larger stances should be efficient for moving on slopes.



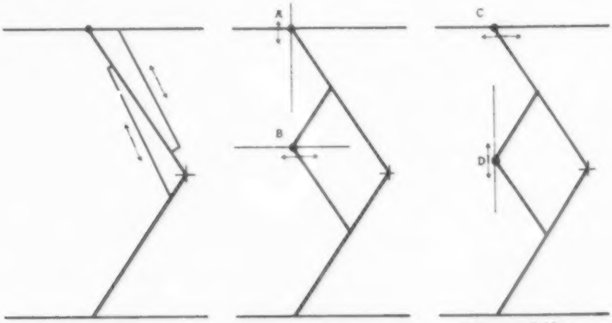
(a) Man type (b) Bird type

Figure 3. The minimum power needed for moving on slopes and the most efficient stance ratios.

The bird-type leg could be regarded as suitable for a foreleg, which must support the vehicle weight when descending forward. The man-type leg was regarded as suitable for a hindleg, which drives the body anytime and must drive it with much power in ascending slopes.

## LEGGED CARRIER AND THE ACTUATOR

Three types of mechanisms were reported as suitable mechanism for carriers for forestry operations[4]: (a) a boom-type mechanism, (b) a normal pantograph mechanism, and (c) a sideways-fallen pantograph mechanism. They were all vertically prolonged as illustrated in Figure 4.



Boom type

Normal pantograph

Sideways-fallen pantograph

Figure 4. Mechanisms for the legs of carriers.

The boom-type mechanism is actuated by two actuators, one moves the thigh and the other moves the lower leg. The foot position must be decided by them in co-operation. The normal pantograph-type is moved separately for the vertical direction and the horizontal direction by two actuators. One actuator moves the foot vertically at Point A, and the other moves the foot horizontally at Point B, by connecting the thigh and lower leg with linkages in the relationship of $L_{11} : L_{12} = L_{01} : L_{02}$ as in Figure 4, so that the vertical foot position is decided by one actuator with no consideration of co-operation with the other actuator. This is the same for the horizontal direction. The sideways-fallen pantograph mechanism is the same as the normal pantograph mechanism, but it is in the position of having fell sideways. At Point C it moves the foot horizontally, and at Point D it moves the foot vertically.

The pantograph mechanism has a pantograph ratio for the relationship with the connecting links. The pantograph ratio a is defined as, $a = L_{11} / ( L_{11} + L_{12} )$. The move of the actuator is enlarged by the reciprocal of a, and the larger is a, the larger is the movement of the foot for the same actuated length of the actuator.

The boom-type mechanism is simple but more difficult in the control of the foot positions than the pantograph mechanisms. The separate moves of the pantograph mechanisms for vertical and horizontal directions should be an advantage for the mechanism of the vehicle. It could be thought that the pantograph mechanisms should be suitable for the carrier.

The driving force at the foot point of the pantograph mechanism is different for the actuating directions at the linkage points. The driving force at the foot q is calculated with the actuating force p by the following equations:

$$q_{11} = \frac{1 - a}{a} p_{11}, \quad q_{12} = \frac{1}{a} p_{12} , \qquad (6)$$

and

$$q_{21} = \frac{1}{a} p_{21}, \quad q_{22} = \frac{1 - a}{a} p_{22} , \qquad (7)$$

where $q_{11}$ is the driving force of the normal type and for the vertical direction, and $q_{12}$ is that of the horizontal direction, while $p_{11}$ and $p_{12}$ are actuate forces for them, respectively. Also $q_{21}$, $q_{22}$, $p_{21}$, and $p_{22}$ are for the sideways-fallen type.

From Equations (6) and (7), the normal-type needs less actuate force for s large driving force in the vertical direction. The sideways-fallen type is calculated to enable a rapid move in the horizontal direction. The carrying mechanisms need enough power to lift the bodies easily. We should regard that much vertical force at the foot is an advantage for the legged mechanisms.

The pantograph ratio changes the movement range, the driving force, and the moving speed at the foot position. We must use a hydraulic system when a full-scale carrier is actuated, and conditions should be considered for the model. When we assume that the vehicle weight is three tons, a is 0.3, and Li = Lo is 1.0 m, a full-scale vehicle should be moved with ordinary hydraulics[1], a hydraulic pressure of 2058 Pa, the inner diameter of the hydraulic cylinder as 60 mm, the diameter of the rod as 40 mm, and a stroke of 600 mm. The expected walking speed would be 1 m/s.

## CONTROL SYSTEM FOR LEGGED MECHANISMS AND THE SIMULATION

The control system for the legged vehicle should be composed of micro processors, a vertical gyro-sensor, and joy-sticks as shown in Figure 5. Here we defined the legged vehicle as a six-legged carrier. The number of legs was decided by trade-off considerations on the expected stability and on the complexity of the controlling system. That is, many contact points with the ground offers good stability for the vehicle, but simultaneous control for the many legs is not easy. The minimum number of legs which enable statical walking is four, but only one leg could be in the free mode, and the other three legs always should support and stabilize vehicle. We added two more legs to obtain more stability than with a four-legged one, with a minimum increase of control complexity.

Microprocessors process control signals in the system. One micro processor is supplied for each leg, and these processors (Sub CPU) are controlled by one upper-level processor (Main CPU). The gyro sensor feedsback vehicle movements to the micro processors. Signals to control the legs are modified by the signal input by the joy-sticks to maneuver the vehicle gait to suit the ground conditions[5].

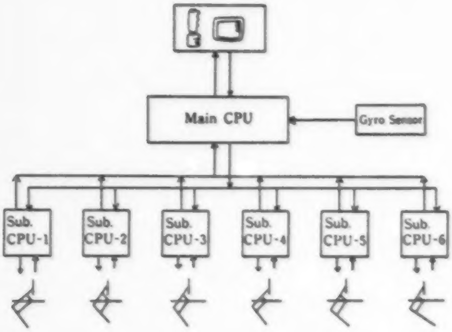


Figure 5. Control system for legs.

The algorithm to control the legs by the above system can be illustrated as in Figure 6. This is a looping algorithm which moves legs in every loop. Signals input to the loop by joy-sticks (A) and the gyro sensor (B) alter the leg movement to increase vehicle stability on slopes. Joy-sticks move leg feet to suitable position to walk over obstacles on the ground, and the hindlegs follow the movement of the first leg and make the vehicle move forward in different directions.

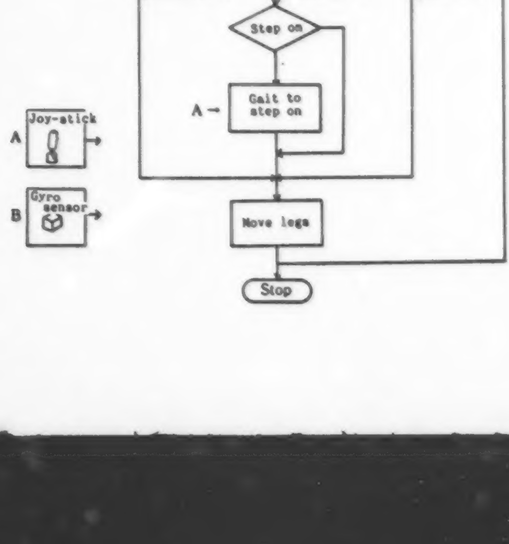


Figure 6. Algorithm to control legs.

Leg movements were simulated with three gaits. They were at $\beta$s of 3/6 (A), 4/6 (B), and 5/6 (C). Figure 7 shows gaits, the leg movements, and the polygon of stability. At least three legs are in the supporting mode as the right side of the figure shows when $\beta$ is 3/6, and this offers a grouping of the six legs into two leg groups and makes their control simple. This gait should be the basic pattern to make the legs move. When $\beta$ grows, more legs would be in the supporting mode at the same time. Only one leg would off the ground when $\beta$ is 5/6. The larger value would be suitable for $\beta$ on rough and steep terrain.

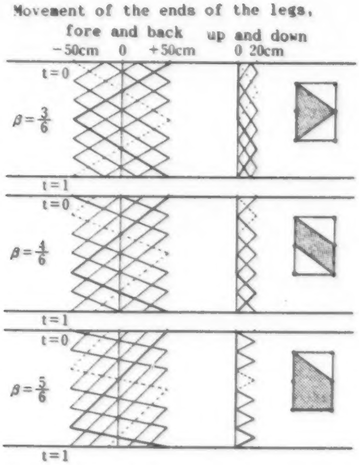


Figure 7. Gaits, the leg movements, and the polygon of stability.

## MODEL OF THE LEGGED VEHICLE AND THE MOVEMENTS

A small experimental model of a legged vehicle was designed and constructed for further study6). The model is 1,110 mm long, 440 mm wide, and about 500 mm high. Weight is designed to be about 441 N, including all equipment, and when excluding the gyro sensor and micro-processor system, it decreased to 294 N. Figure 8 shows the model.

Driving forces at the foot were measured to enable discussion of the design. The mechanism to actuate the legs was a kind of linear slider. The sliding part was forced to move along a sliding rail by a screw knot and a electro-motor-driven screw shaft. The mechanism was designed to obtain suitable force by the following equation:

$$F = \frac{2\pi \cdot \eta \cdot T}{1\times 10^{-3}}\,, \qquad (8)$$

where F is the driving force at the sliding part (N), $\eta$ is the efficiency of the screw-shaft mechanism, T is the torque of the motor-driven gear on the screw shaft (N·m), and l is the pitch of the screw shaft (mm). The value of $\eta$ was about 0.26 empirically.

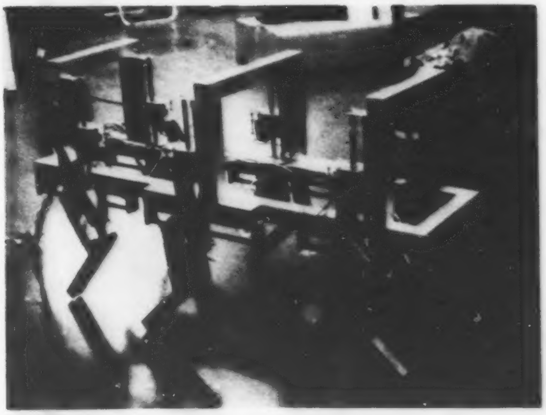


Figure 8. The small legged-carrier model.
Note: The right side is the front part; the forelegs at the front first position are bird-type and the others are man-type.

Driving forces were measured by a distortion gage for the vertical and horizontal directions. For the latter direction, the leg had 37.2 N, and this lead to 0.363 as the efficiency; this should be lessened without acceleration. The leg had 52.9 N for the vertical direction, and the efficiency was 0.258. We understood that the expected driving forces were obtained for both directions. Sufficient driving forces would be derived by supplying the motor with suitable current.

Speed of the foot was measured in the both the horizontal and vertical directions. Legs moved 0.654 m/s, back and forth, at the maximum, and 0.268 m/s, up and down, at the maximum. This satisfied the designing conditions.

## CONCLUSIONS

Legged mechanisms could be regarded as having sufficient ability as carriers of forestry vehicles. There can be found many advantages such as slope stability, trafficability over rough terrain, and less disturbance of ground surfaces, but the control of multi-legs is not easy and would be accomplished with a sensor-micro processor system.

Suitable gaits for various ground conditions should be made clear. The system to simulate leg movements and the carrier walks, now in the computer, will be implemented with the experimental vehicle model.

The control system must govern six legs simultaneously. The first leg should be moved by the manual control with the joy-stick, and the following legs would follow the foot positions.

We need forestry machines urgently, especially for silvicultural operations. Mechanization of this work on steep slopes and rough terrain could be accomplished with a vehicle with a legged-carrier mechanism, but should be made efficient and safe at their operation.

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# A METHOD TO ANALYZE CHEMICALLY THE FOLIAGE OF PINACEAE

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FDC: 164.5: 160.2: 892: 174.7

## SUMMARY

A method to analyze extractive substances of tree foliage is suggested. The composition of terpenoids contained by the foliar fraction of Scots pine, Norway spruce and Siberian fir has been determined. Intraspecific variations between the terpenoids recovered from needles and shoots, respectively, as well as compounds most typical for the given species, have been established. The composition of terpenoids contained by the needle fraction is shown to be highly data-capacious for an understanding of chemosystematics of Pinaceae.

Keywords: Pinaceae, Pinus silvestris L., Picea abies (L.) Karst., Abies sibirica L., tree foliage, terpenoids

## INTRODUCTION

In the Soviet Union, the chemical processing of conifer foliage is, since the 1950ies, done on a systematic basis. Quite a number of plants and shops, built over these years, turn out predominantely the following products: chlorophyll-carotene paste, sodium chlorophyllin, conifer needle wax, ether oil, a repellent against rodents for horticultural use, an insecticide for pest control in agriculture.

Further progress in this direction is seriously hampered by an inadequate knowledge of the chemical composition of extractive substances recovered from conifer foliage (needles and deneedled shoots). The same refers to the above products, a mix of compounds as they are, and the biological activity of individual substances they contain. To fill in the gap, studied is the chemical composition of needles and deneedled shoots (elements making up conifer foliage) for the following principal conifer species of the Soviet Union: Scots pine (Pinus silvestris L.), Norway spruce (Picea aboes (L.) Karst.), Siberian fir (Abies sibirica L.), Siberian cedar (Pinus sibirica Du Tour).

## EXPERIMENTAL METHODS

Foliar extracts have, in this study, been subjected to analyses following pattern I, which is distinguished by the use of a polar solvent for extraction and removal of the extract's non-polar fraction by petroleum ether. The said ether-soluble substances are further separated, in a conventional manner, into acids and neutral substances, subsequently chromatographed on Silica gel, with fractions, differing in the polarity of the compounds they contain, as the result.

Thereupon, acid fractions are methylated, methyl ethers of resinous and higher falty acids are GLC- analyzed, components more polar than resinous and fatty acids are isolated by using column chromatography on Silica gel with Argentum nitrate added. Methyl ethers of even higher polarity oxy-acids are, for the most complicated cases of isolation, acetylated in order to isolate acetates of primary and secondary oxy-acids from acids having a tertiary hydroxyl group, which, under the conditions imposed, failed to acetylate. Such an approach allows the polarity of methyl ethers of primary hydroxyl group containing oxy-acids to be lowered and smoothly isolated from those of tertiary hydroxyl group, thus alleviating isolation within a fraction, where chromatographic properties of its constituents are close.

When dealing with acids derived from fir foliage, which consist mainly of hard-to-break triterpene oxy- and oxo-ones, a treatment, prior to methylation, by sodium bicarbonate (Na $HCO_3$) has been found useful. This treatment has enabled us to isolate more "strong" acids having two carboxyl groups from those said to be "weak" and lactones (Fig.1.).

Neutral substances are, for the start, broken down into the following fractions: hydrocarbons, complex esters, triglicerides, low polarity tertiary alcohols, sterols and polyoxy-compounds (Fig.1.).

Composed of hydrocarbons is the fractions to be eluated from the column, $R_f$ value greater than reference squalene. The former contain alkanes and terpenes which can be isolated on Silica gel with Argentum added. A fraction, having, with TLC, value $R_f$ higher than squalene and lower than bornylacetate, contains complex esters comprising esters of aliphatic alcohols, sterols, triterpene alcohols with higher falty acids, methyl (pine, fir) and ethyl (spruce) ethers of resinous acids,acetates of polyprenols, oxides and aldehydes.

This fraction, because of numerous different groups of substances that make it up, is rather difficult for chromatographic break-down into separate groups of compounds andindividual substances. To render the fraction less complicated as to its composition, chemical methods have been applied. The fraction has, at first, been subjected to alkaline hydrolisys. After conventional treatment, the aciduous component of the complex esters, sterols, triterpene and aliphatic alcohols has been obtained. The latter may be easily isolated by column chromatography on Silica gel from aldehydes, oxides and methyl ethers of resinous acids. The composition of acids has been determined by GLC method.

Aldehydes are isolated from oxides and methyl ethers of resinous acids on the column with Silica gel subsequent to their reduction, by NaBH$_4$, to alcohols. Their composition has been determined by GLC method, while that of oxides and ethers of resinous acid - by chromatomass spectrometry, PMR. This method has been successfully applied by V.Raldugin to the analyses of turpentine gum.

The following fraction, having, with TLC, R$_f$ value equal to bornylacetate and lower than R$_f$ value for nonacosanol-10, is composed of acetates of mono- and diterpene alcohols and triglicerides. Prior to alkaline hydrolyses, its fractions are to be GLC analyzed to determine the composition of alcohol acetates. After alkaline hydrolyses the acids isolated are likewise GLC analyzed, the alcohols have been isolated chromatographically, their structure determined by spectral methods.

Tertiary monopolar diterpene and sesquiterpene alcohols are contained by fractions to be eluated out of chromatographic column, following that of nonacosanol-10. Individual compounds have been isolated on Silica gel with Argentum nitrate. Abienols, epimanool, isocembrol, geranylgeraniol, muurolols, germacrene alcohol, nerolidol have been identified in this fraction.

Subsequent to nonpolar tertiary alcohols and up to sitosterol, the fractions are composed of primary diterpene alcohols and nor-diterpene alcohols, fatty alcohols, triterpene alcohols, tertiary mono- and sesquiterpene alcohols. Among them identified are cycloartenol, 24-methylene-cycloartenol, tricyclic diterpene alcohols of abietinol and pimaric type, cadinols, terpineol, geranylgeraniol and other alcohols. To isolate them, a method of acetylating primary and secondary alcohols by acetate anhydride in piridine and isolating acetates obtained from nonacetylable tertiary alcohols by way of chromatography on Silica gel, is used.Subsequent to that, individual substances are isolated out of the group of acetates and nonacetylable alcohols, using Silica gel with Argentum nitrate.

Sterol fraction contains mainly two compounds - sitosterol and campesterol, their relationship determined by GLC.

The given method for analyzing high-complexity natural substances contained by conifer foliage extracts provides for the composition of their constituents established, intraspecific differences between needle- and shoot-derived compounds, as well as the respective interspecific differences between diverse conifers elucidated, individual compounds isolated and their biological activity inquired into.

## RESULTS

The results, following patterns 1 and 2, of the analyses of the compounds extracted from the conifer needles and deneedled shoots (branches) are presented in Table 1.

Table 1: Composition of neutral substances

| Groups of substances and their components | Pinus silvestris needles | Pinus silvestris shoots | Picea abies needles | Picea abies shoots | Abies sibirica n. | Abies sibirica sh. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1. Hydrocarbons | 3.6 | 4.3 | 5.3 | 4.1 | 5.8 | 8.7 |
| Alkanes $C_{16}$-$C_{33}$ | 0.6 | 0.4 | 2.2 | 3.2 | 1.8 | 3.2 |
| Terpenes: | 3.0 | 3.9 | 3.1 | 0.9 | 4.0 | 5.5 |
| mono- and sesquiterpenes | 1.9 | 1.8 | 1.4 | 0.4 | 3.3 | 4.6 |
| diterpenes | 0.9 | 2.0 | 1.0 | 0.4 | 0.4 | 0.5 |
| squalene | 0.1 | 0.1 | 0.4 | 0.1 | 0.2 | 0.3 |
| 2. Aldehydes | 0.2 | 1.5 | 1.0 | 0.5 | 0.2 | 0.5 |
| sandaracopimarinal | + | + | + | + | - | |
| pimarinal | + | 0.9 | + | + | - | |
| isopimarinal | 0.1 | 0.4 | 0.5 | 0.1 | + | 0.2 |
| dehydroabietinal | 0.1 | 0.2 | 0.4 | 0.3 | + | 0.2 |
| abietinal | + | + | + | + | - | |
| neoabietinal | + | + | + | + | - | |
| 3. Oxides | 1.0 | 0.3 | 0.1 | 0.1 | 0.3 | 0.3 |
| epimanoyloxide | 0.9 | 0.1 | 1:1 | 1:1 | 0.1 | 0.1 |
| manoyloxide | - | - | | | - | - |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 4.Methylesters of resinous acids | 0.5 | 0.4 | + | 0.5 | + | + |
| methylpimarate | + | + | – | – | – | – |
| methyllevopimarate + methylpalustrate | + | + | – | – | – | – |
| methylisopimarate | + | + | – | – | – | – |
| methyldehydroabietate | 0.3 | 0.2 | + | 0.2 | + | + |
| methylabietate | 0.2 | 0.1 | – | – | – | – |
| methylneoabietate | + | + | – | – | – | – |
| ethylpimarate | – | – | – | + | – | |
| ethylisopimarate | – | – | + | + | – | – |
| ethyldehydroabietate | – | – | + | 0.6 | – | – |
| ethylabietate | – | – | – | 0.2 | – | – |
| ethylneoabietate | – | – | – | 0.3 | – | – |
| 5.Complex esters | 16.5 | 35.4 | 45.6 | 42.2 | 46.4 | 35.3 |
| Acetates of alcohols | 7.9 | 0.6 | 31.0 | 0.8 | 34.5 | 14.9 |
| α-terpineol | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | 0.2 |
| borneol | + | + | 1.0 | 0.5 | 16.2 | 14.7 |
| geraniol | + | + | – | – | 0.3 | + |
| phenhol | – | – | – | – | 0.1 | + |
| geranylgeraniol | 0.1 | + | – | – | – | – |
| 3β-oxi-trans-biformen | – | 0.1 | – | – | – | – |
| prenols | 7.1 | – | 29.5 | – | 17.5 | – |
| longiborneol | – | – | – | – | 0.1 | + |
| Esters of alcohols and fatty acids | 8.4 | 33.4 | 14.3 | 41.0 | 12.0 | 18.4 |
| fatty alcohols | 0.2 | 1.8 | 1.2 | 1.9 | 1.6 | 1.9 |
| citrostadienol | – | – | 0.1 | + | 0.3 | + |
| cycloartenol | 0.3 | 0.2 | 0.2 | 0.8 | 0.2 | 0.2 |
| 24-methylenecycloartanol | 0.5 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 |
| sitosterol | 2.4 | 6.2 | 3.2 | 8.8 | 3.8 | 6.4 |
| campesterol | 0.1 | 0.2 | 0.1 | 1.0 | 1.2 | 1.6 |
| cholesterol | – | + | – | – | – | – |
| stigmasterol | + | 0.2 | – | – | – | – |
| fatty acids | 4.0 | 19.7 | 4.3 | 25.2 | 3.5 | 6.2 |
| 6.Diglycerides | + | + | + | 3.0 | + | + |
| Triglycerides | + | 1.0 | + | 7.0 | + | 10.0 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 7. Ethers: | 0.5 | 2.6 | + | 1.0 | 6.0 | 2.6 |
| 3α-methoxiserrat-14-en-21β-ol | - | - | - | 0.1 | - | - |
| 21α-methoxiserrat-14-en-3-on | - | - | - | 0.3 | - | - |
| 3β-meth oxiserrat-14-en-21β-ol | - | - | - | 0.1 | - | - |
| 3β,21α-dimethoxiserrat-14-en | - | 0.8 | - | 0.1 | - | - |
| 3β-methoxiserrat-14-en-21-on | - | 1.0 | - | - | - | - |
| serrat-14-en-3,21-dion | - | 0.6 | - | - | - | - |
| 3β-methoxiserrat-14-en-21α-ol | - | 0.2 | - | - | - | - |
| methyl-15-hydroxidehydroabietate | 0.2 | + | + | 0.2 | - | - |
| abieslactone | - | - | - | - | - | 0.3 |
| (22Z)-3-oxo-9β-lanosta-7,22,24-trien-26,23-olide | - | - | - | - | 2.0 | 0.5 |
| (22Z)-3-oxolanosta-8(9),22,24-trien-26,23-olide | - | - | - | - | 1.8 | + |
| p-methoxiacetophenon | + | + | - | - | - | - |
| dimethyl ether of pinosylvin | + | + | - | - | - | - |
| lactones of unknown composition | 0.2 | - | - | - | 2.2 | 1.8 |
| 8. Alcohols | 59.5 | 25.7 | 29.0 | 33.0 | 37.3 | 38.0 |
| α-terpineol | 0.5 | 0.3 | 0.2 | 1.0 | 0.3 | 0.2 |
| borneol | + | + | 1.0 | 0.5 | 6.2 | 6.2 |
| geraniol | + | + | + | + | + | + |
| phenhol | - | - | + | + | + | + |
| nerolidol | - | - | - | - | 0.1 | + |
| 7R- and 7S-bisabolols 4:1 |  | - | - | - | 2.5 | 1.7 |
| δ-cadinol | 0.3 | 0.3 | 0.3 | 2.5 | - | - |
| α-cadinol | + | + | - | - | - | - |
| T-cadinol | + | + | - | - | - | - |
| T-muurolol | 0.1 | + | - | - | - | - |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 5S,8S-germacra-IE,6E-dien-5-ol | 0.1 | - | - | - | - | - |
| longiborneol | - | - | - | - | 0.2 | + |
| seline-6-en-4 β -ol | - | - | - | - | 0.9 | 0.2 |
| epicubenol | - | - | - | - | 0.3 | 0.1 |
| cubebol<br>epicubebol 1:1 | - | - | - | - | 0.5 | 0.7 |
| phytol | 0.3 | - | 1.0 | - | 0.9 | - |
| geranylgeraniol | 0.2 | - | 0.2 | + | - | - |
| geranyllinalool | - | - | 0.2 | 0.1 | - | - |
| isocembrol | - | - | - | 0.7 | - | - |
| cis-abienol | - | 2.0 | - | 0.3 | 0.5 | 13.9 |
| isoabienol | 40.0 | - | - | - | - | - |
| epimanool | - | - | 2.4 | 1.1 | 0.7 | 0.3 |
| 3β-oxi-trans-biformen | - | 1.5 | - | - | - | - |
| epitorulosol | - | - | 1.2 | + | - | - |
| pimarinol | 0.5 | 0.6 | - | - | - | - |
| sandaracopimarinol | 0.1 | + | - | - | - | - |
| isopimarinol | 0.2 | 0.3 | 1.0 | 1.5 | + | + |
| abietinol | 0.3 | 0.1 | 0.1 | + | + | + |
| dehydroabietinol | 0.3 | 0.2 | 1.0 | 1.0 | + | + |
| neoabietinol | 0.1 | + | 0.3 | 0.5 | - | - |
| cycloartenol | 0.5 | 0.2 | 0.5 | 0.7 | + | + |
| 24-methylene-cycloartanol | 0.2 | 0.1 | 1.5 | 2.0 | + | + |
| sitosterol | 12.2 | 9.8 | 5.3 | 13.5 | 7.7 | 8.1 |
| campesterol | 0.5 | 0.2 | 0.5 | 1.8 | 1.0 | 2.0 |
| prenols | + | - | 3.6 | - | - | - |
| nonacosanol-10 | 1.3 | - | 1.7 | - | 11.3 | - |
| fatty alcohols | 1.0 | 2.4 | 3.0 | 3.5 | 2.0 | 2.5 |

(+) - containing the substance less than 0.1 %

The data for the composition of the neutral substances found in the foliage of the three Pinaceae suggest that the majority of the groups of compounds are typical for all the species studied. Here are some compounds present in both needles and shoots: sitosterol, campesterol, cycloartenol,24-methylene-cycloartenol, fatty alcohols, alkanes, quite a number of terpenes, especially monoterpenes, oxides, borneol, $\alpha$ -terpineol and others. There are compounds, however, traceable ,traceable, for the given species, in shoots only, or only in needles. So, in shoots only, cis-abienol has been traced in considerable amount, while for needles the same is true for phytol, nonacosanol-10, prenols. Serratenous triterpenes, absent in needles, have been detected in spruce and pine shoots. The content of glycerides and sterols is higher in branches than in needles. Compounds, typical only for a separate species, or individual foliage elements within the species, have also been determined.

The following compounds in a high content are typical for the extractive substances of Scots pine needles: isoabienol, sesquiterpenes of the cadinane and muurolane group and their oxygen containing derivatives, acids of the labdane type of two series: 4-epiimbricatoloic and anticopaloic.

The composition of pine needle extractives has been found to vary depending upon the geographical occurrence of pine. So, isoabienol has not been detected in pine needles of Czechoslovakia origin, while those of the Baltic area (Latvia) and further to the West show up a new component - epimanoyloxid-19-acid, undetected in the needle samples gathered over an area of the USSR to the East of Baltic,(the needle samples for this study have been harvested over an area between Czechoslovakia in the West to the Krasnoyarsk Territory in the East).

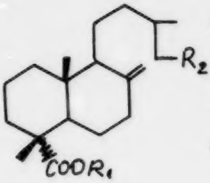
Table 2 presents the composition of the acid fraction of the extractives of pine foliage of the Leningrad area of growth.

Table: The composition of resinous acids contained by the Scots pine needles and shoots, in per cent of the total amount of free acids

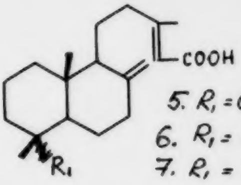
| Component | Needles | Shoots |
|---|---|---|
| 1 | 2 | 3 |
| Higher fatty acids | 11.5 | 12.2 |
| Resinous acids | 21.3 | 42.5 |
| pimaric | 0.2 | 4.0 |
| palustric + levopimaric | 0.6 | 1.2 |
| isopimaric | 0.5 | 10.6 |
| dehydroabietic | 4.2 | 14.6 |
| abietic | 15.6 | 11.7 |
| Polar acids | 67.2 | 45.3 |
| monomethyl ester of pinifolic acid (1) | 23.7 | + |
| pinifolic acid (2) | 6.0 | + |
| 18-acetylanticopalic (5) | 1.3 | 1.2 |
| 18-oxianticopalic (6) | 1.3 | 0.4 |

| 1 | 2 | 3 |
|---|---|---|
| 15-oxi-4-epiimbricatoloic (3) | 1.4 | 0.4 |
| 15-al-4-epiimbricataloic (4) | 1.3 | + |
| dehydropinifoloc (7) | 0.5 | - |
| 7-ketodehydroabietic (11) | - | 1.3 |
| 12-oxiabietic (8) | - | 0.4 |
| 12-ketoabietic (9) | - | 0.2 |
| 12-oxidehydroabietic (12) | - | 0.5 |
| 7α -oxidehydroabietic (13) | - | 0.2 |
| 15-oxidehydroabietic (14) | - | 0.1 |
| 15-oxiabietic (10) | - | 0.1 |
| monomethyl ester of pinosylvan | 1.0 | 0.4 |

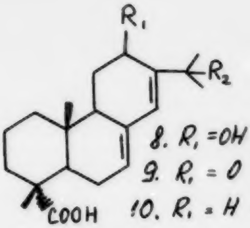
(+) - the content of substance is less than 0.1 %



1. $R_1 = CH_3$ $R_2 = COOH$
2. $R_1 = H$ $R_2 = COOH$
3. $R_1 = H$ $R_2 = CH_2OH$
4. $R_1 = H$ $R_2 = CHO$

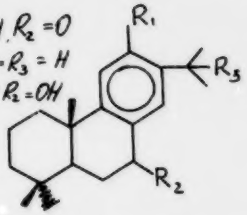


5. $R_1 = CH_2OAc$
6. $R_1 = CH_2OH$
7. $R_1 = COOH$

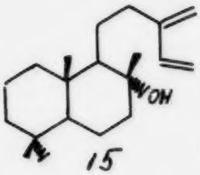


8. $R_1 = OH$ $R_2 = H$
9. $R_1 = O$ $R_2 = H$
10. $R_1 = H$ $R_2 = OH$

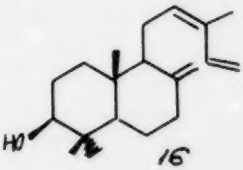
11. $R_1 = R_3 = H$, $R_2 = O$
12. $R_1 = OH$ $R_2 = R_3 = H$
13. $R_1 = R_3 = H$ $R_2 = OH$
14. $R_1 = R_2 = H$ $R_3 = OH$



Isoabienol (15), 3β-oxi-trans-biformen (16) acids of labdane type are typical for tree foliage and have not earlier been detected in other parts of tree (extractive substances of stem, turpentine gum), as well as in other species, studied earlier.

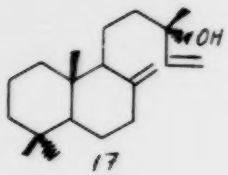


15

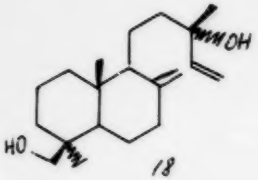


16

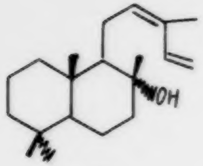
Extractive substances of Norway spruce needles differ from those of branches by a high content of prenols, epimanool (17), epitorulosol (18), nonacasanol-10. Cis-abienol (19), triterpenoids of serratenous type, isocembrol (20) have been found only in branches. Isocembrol, geranyllinalool, epitorulosol, citrostadienol are typical for the foliage fraction of spruce



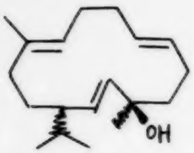
17



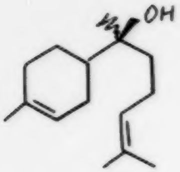
18



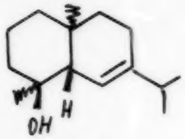
19



The extractive substances of Siberian fir foliage and those of other species studied differ in the composition of sesquiterpene alcohols, the presence of lactones and the acids of lanostane type, as well as in a high content of borneol and bornylacetat. Bisabolol (21), 4S, 5S, 10S-selina-6-en-4-ol (22) and some other sesquiterpene alcohols have been found only in the foliage of Siberian fir.

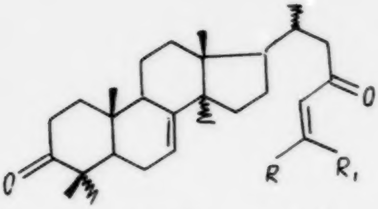


21

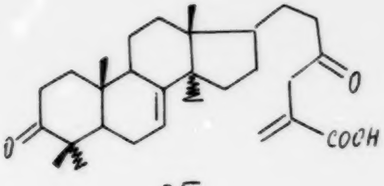


22

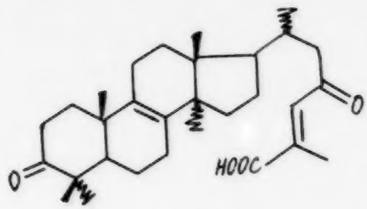
Diketoacid (23) and its isomers (24, 25, 26) have been found in both needles and branches of Siberian fir. The acids of mariesic type (27) habe been detected only in needles, while abiesonic (28) and abiesolodic (29) acids - in shoots only.



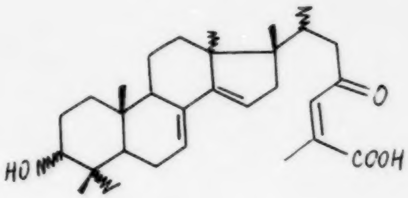
23 $R = COOH$ $R_1 = H$
24. $R = CH_3$ $R_1 = COOH$



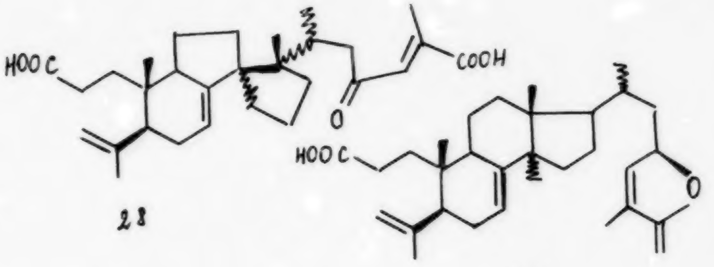
25



26



27



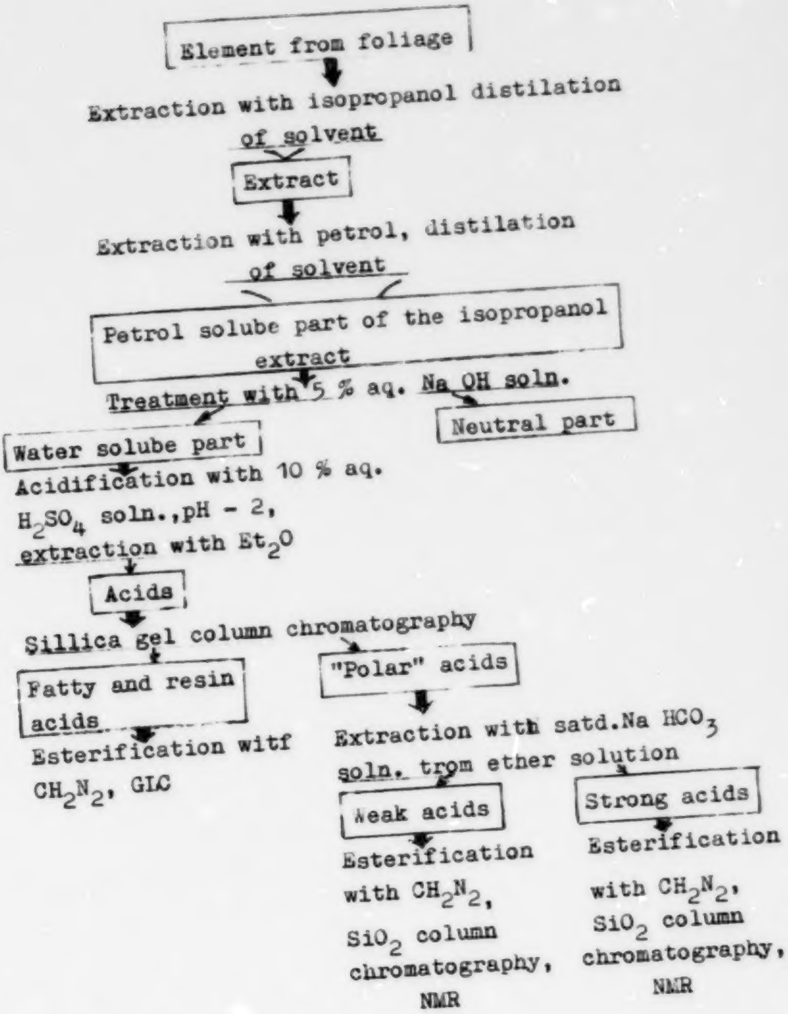
28

26

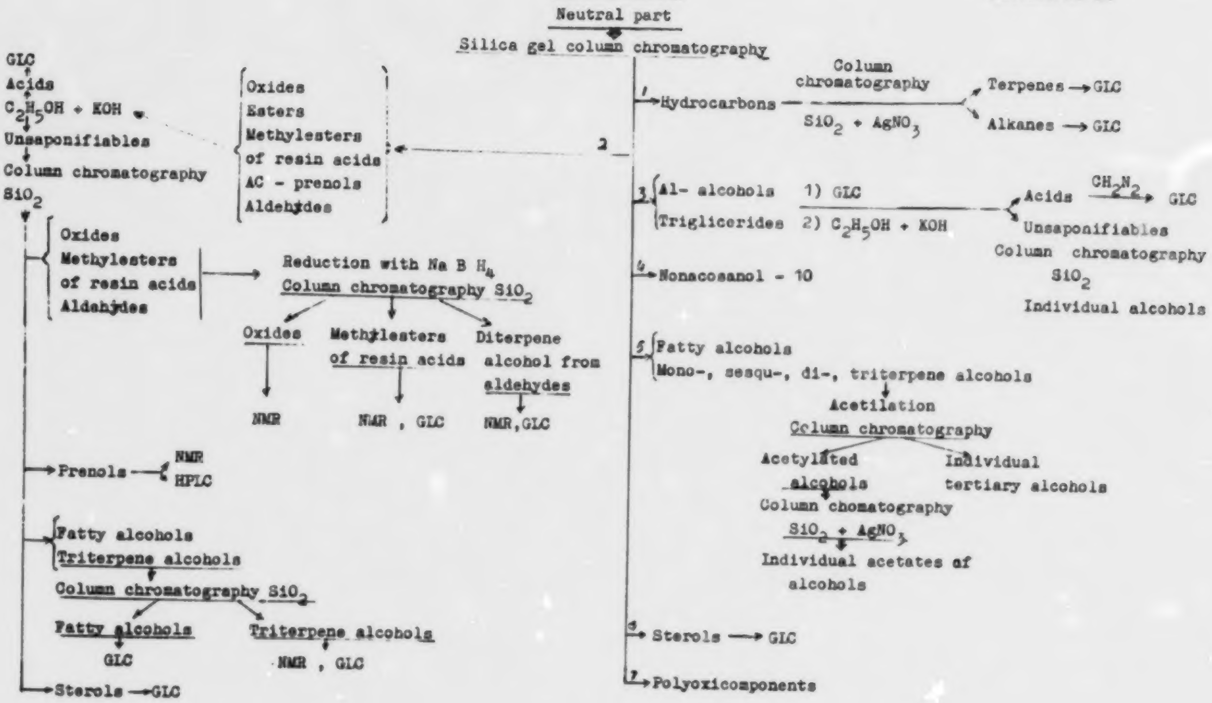
Proceeding from the data on foliar extracts' chemical composition, the process of metabolism for a number of compounds has been suggested. Some compounds or their groups found to exhibit insecticide, antifeeding or repelling proper ties have been studied with a view to their application in agriculture for pest and disease control. Likewise, some compounds have been tested for their activity against certain strains of microorganisms or infective viruses, as well as for their immunomodulating, hypotensive and reparative properties.

Methods of processing tree foliage, based on the knowledge of its extracts' composition and properties, have been suggested.

Pattern No 1


Element from foliage
Extraction with isopropanol distilation of solvent
Extract
Extraction with petrol, distilation of solvent
Petrol solube part of the isopropanol extract
Treatment with 5 % aq. Na OH soln.
Water solube part
Neutral part
Acidification with 10 % aq. $H_2SO_4$ soln., pH - 2, extraction with $Et_2O$
Acids
Sillica gel column chromatography
Fatty and resin acids
"Polar" acids
Esterification witf $CH_2N_2$, GLC
Extraction with satd. Na $HCO_3$ soln. trom ether solution
Weak acids
Strong acids
Esterification with $CH_2N_2$, $SiO_2$ column chromatography, NMR
Esterification with $CH_2N_2$, $SiO_2$ column chromatography, NMR

Pattern No 2.


Neutral part
Silica gel column chromatography
1 Hydrocarbons
Column chromatography
$SiO_2 + AgNO_3$
Terpenes → GLC
Alkanes → GLC
2
3 Al- alcohols
Triglicerides
1) GLC
2) $C_2H_5OH$ + KOH
Acids
$CH_2N_2$
GLC
Unsaponifiables
Column chromatography
$SiO_2$
Individual alcohols
4 Nonacosanol - 10
5 Fatty alcohols
Mono-, sesqu-, di-, triterpene alcohols
Acetilation
Column chromatography
Acetylated alcohols
Individual tertiary alcohols
Column chomatography
$SiO_2 + AgNO_3$
Individual acetates of alcohols
6 Sterols → GLC
7 Polyoxicomponents
Oxides
Esters
Methylesters of resin acids
AC - prenols
Aldehydes
GLC
Acids
$C_2H_5OH$ + KOH
Unsaponifiables
Column chromatography
$SiO_2$
Oxides
Methylesters of resin acids
Aldehydes
Reduction with Na B $H_4$
Column chromatography $SiO_2$
Oxides
Methylesters of resin acids
Diterpene alcohol from aldehydes
NMR
NMR , GLC
NMR, GLC
Prenols
NMR
HPLC
Fatty alcohols
Triterpene alcohols
Column chromatography $SiO_2$
Fatty alcohols
GLC
Triterpene alcohols
NMR , GLC
Sterols → GLC

# THE NEEDS FOR FUTURE RESEARCH IN THE PERSPECTIVE OF 10-20 YEARS WITHIN STAND ESTABLISHMENT (FROM LATIN-AMERICAN OUTLOOK)

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FDC: 238: 165.3: (8)

Modern silviculture in the tropics started in the beginning of the century at the Paulista Railway Company. After several failures to cultivate native species for poles and railway sleepers, trees of the genus *Eucalyptus* showed good potential under the same conditions. As a result, around 250 eucalipt species were cultivated experimentally during the following years while methods of nursery management and field operations were developed. Before the World War II, intensive silviculture was already standardized for eucalipts. In the last decades a large amount of genetic material of eucalipts and tropical pines were introduced in Brazil. At the same time, techniques of savanna soils management made possible the use of lower latitude areas for plantation forestry. The last twenty years were characterized by vegetative propagation in large plantations and the challenge of planting pure stands of exotic trees in equatorial areas at JARI Project and Amapa Celulose Company. This last forestry frontier is now a reality since the advances of fitting species and provenances to the amazonic environment are already operational at a profitable level. Operations are described, focusing in what will be the needs in terms of future research towards an even higher competitiveness. Opportunities in biotechnology are also discussed, such as "in vitro" propagation, already being used. Another technique discussed is isozyme analysis, which has shown potential in forestry. Advances in other areas like somatic embryogenesis leading to clonal "seeds" and genome transformation for herbicide resistance are also being accompanied in order to recommend action from industry when appropriate.

# CONTAINERIZED NURSERY PRODUCTION IN HAITI: LESSONS LEARNED AND RESEARCH NEEDS

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FDC: 232.329.6: 26: 176.1: (729.4)

## SUMMARY

Eight years of experience with containerized tropical nursery production in Haitian agroforestry are examined. Containers, potting medium, seed & germplasm improvement, species selection and species/site matching, microsymbiants, stock quality and cultural procedures are reviewed in the context of identification of future research needs in tropical hardwood containerized nursery production.

**KEYWORDS**: Tropical nursery production, agroforestry, hardwood, research.

## INTRODUCTION

Haiti, a small Caribbean nation occupying the mountainous western third of the island of Hispaniola, was once almost entirely covered by forest. However, years of deforestation and ecological mismanagement have led to widespread environmental degradation and severe soil erosion. Deforestation has occurred due to demand for agricultural land and because Haitians have traditionally depended on firewood and charcoal for their cooking and heating energy requirements. With the original forest cover having been nearly completely removed, currently only one small forest of 34,000 hectares remains (Ashley, M. 1989). The majority of Haiti's lands are now covered with sparse brushland, grass or exposed rock. With one of the lowest levels of per capita Gross National Products in the Western Hemisphere ($300) (Population Reference Bureau, 1988), Haiti has one of the highest ratios of rural population density to arable land (700 persons per arable hectare) (USAID, 1984). Population pressures have increased the demand for arable land, and exacerbated soil erosion on steep mountainside farms with subsequent hydrologic instability, resulting in reduced agricultural production and intensified rural poverty.

In an effort to reverse these trends, the United States Agency for International Development (U.S.A.I.D.) launched the Agroforestry Outreach Project (AOP) in 1981 to promote the planting of trees as a cash crop. Based on a socio-cultural analysis of Haitian peasant needs and attitudes regarding the planting and use of trees, the project aims to motivate farmers to plant and protect trees in their fields (Murray, 1981; Smucker, 1981). Implemented through non—governmental organizations (NGOs), such as religious missions and grassroots development groups, and lead by the Pan American Development Foundation and CARE the project encourages the practice of cropping trees on private holdings to increase farmer's incomes and the productivity of their land.

Over the past 8 years the AOP has developed an efficient, technologically appropriate system for the mass production of containerized tree seedlings in a country of marginal resources and infrastructure. The project's 50 regional containerized nurseries produce and distribute nearly ten million trees per year to participating farmers. The projects' achievements have been buttressed in part by basic applied research conducted by the projects research component (currently SECID/Auburn University.

Most worldwide programs attempting to modernize nursery production of tropical hardwood production are essentially starting from scratch. Much of what has been learned from decades of research conducted on temperate species or for tropical/subtropical pines is simply not applicable for hardwoods in the tropical, developing country context. This paper will summarize what has been learned in Haiti and will identify future research needs for improved nursery production of tropical hardwood tree species.

## CONTAINERIZED NURSERIES - THE CONTAINER

By and large, the majority of tree seedlings produced in the tropics are grown in large plastic sacs. The plastic sac however, requires large amounts of soil medium and discourages good lateral root development. Roots commonly exit the sac and grow into the soil below, or else spiral at the base of the sac. If the sac lacks holes at the base, a perched water table may exist, limiting aeration and root growth. Seedlings grown in large sacs are heavy, bulky and thus hamper the distribution of large numbers of seedlings to each farmer.

Due to these limitations and the poor survival of bare root seedlings in the tropics, the AOP uses 2 types of rigid wall containers, the Rootrainer by Spencer-Lemaire and the Winstrip by Winstrip Incorporated. Both containers have produced tens of millions of high quality tree seedlings of over 40 tropical species. With this considerable experience, it is clear that containerized seedlings with small root plugs can achieve high survival rates in the tropics, even under adverse social forestry/agroforestry conditions (Fig. 1). Compared to plastic sacks, these smaller, lighter, container grown seedlings are much easier to distribute, permitting the mass distribution of tree seedlings to farmers living in remote areas lacking any vehicular access. Rootrainers are easily opened to check root development and soil moisture, and thus are especially appropriate for nursery production in developing countries where hand watering methods are the norm. Using a light colored container also significantly reduces potting medium temperature and subsequent root stress. Lateral root development in both container systems is prolific. Spiral roots are avoided because vertical ribs direct the laterals to the bottom where they are air pruned. Direct nursery production costs are relatively low, approximately U.S. $.06 per seedling (Goodwin et al, 1989).

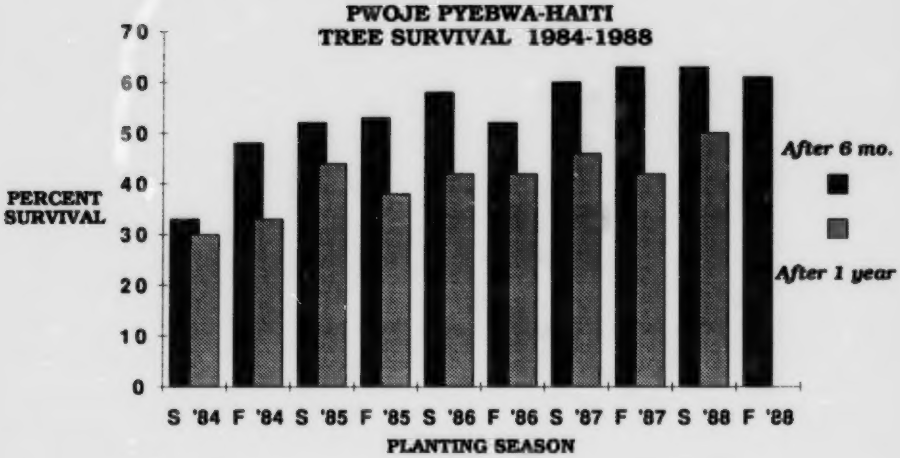

Fig. 1. Tree Survival After 6 Months and One Year, 1984-1988, Haiti.

Further research and development is needed to prolong the life and reduce the costs of the container systems, reduce root egress into adjacent cells and improve air pruning and lateral root development along the sides of the cells. It appears that at some point, increased soil volume is linked to improved survival, yet it remains unclear what minimum soil volume will begin to increase post-planting survival.

## POTTING MEDIUM

The AOP currently uses imported soil medium (Fafard II) or a variety of local mixes either commercially produced or mixed at the nurseries. Haiti Mix, a commercially produced local medium is composed of 70% composted sugar cane bagasse, 15% unmilled rice hulls, 15% silty-clay soil, a small amount of Canadian peat moss (quantity depending upon tree species) and chemical fertilizer. Haiti Mix has been shown to perform similarly to imported potting media (Reid 1989). Other, non-commercial local mixes (produced at the nursery) incorporate animal manures, composted organic materials and soil to form a planting medium of variable but usually adequate quality. While mix uniformity is uneven in the local non-commercial mixes, performance normally approximates that of the imported soil medium. Local mixes are considered superior to imported media due to lower costs and because they utilize local materials and labor.

Further research is needed to formulate a potting medium similar to Haiti Mix, but based on a more rigorous scientific analysis of the medium's physical and chemical properties, including potentially toxic by-products of composting. The value and efficacy of soil "pasteurization" or sterilization methods via heat generated by composting or solarization needs to be investigated. Further, disease prevention benefits gained by using non-sterile, microbiologically balanced soil medium need to be weighted against the use of "sterile" potting media. Methods to accelerate the decomposition of organic materials such as bagasse or coconut husk fibers need to be researched. Specific, easily-measurable criteria to evaluate the degree of decomposition of these and other organic materials need to be established in order to avoid using incompletely decomposed material in potting mixes.

## SEED AND GERMPLASM IMPROVEMENT

The AOP has had a seed and germplasm improvement component since 1988. Recent activities include the identification of phenotypically superior trees, establishment of provenance and progeny trials, and seed orchard or seed multiplication areas for both native and exotic species. Further genetic improvement needs to be done with the following species: Cassia siamea, Acacia auriculiformis, Gliricidia sepium, Calliandra calothyrsus, Grevillia robusta, Acacia melanoxylon, Azadirachta indica, Pinus occidentalis, and Acacia mearnsii. Research is needed to learn more about the phenology and reproductive biology of these native and exotic tropical species. For example, Gliricidia sepium is an exotic species highly valued for its excellent performance in living terraces, yet seed is in critically short supply due to erratic or non-existent local seed crops. Knowledge of the biology of this and other species in Haiti would be of practical use in Haiti and elsewhere.

Basic research identifying the ecological requirements for each species is absolutely required if species/site matching, and thus better survival and growth, are to be achieved. This knowledge is especially important in areas where sites are severely degraded, which is the case over much of Haiti.

There is also an excellent opportunity to significantly improve the genetic quality of tropical hardwood seed through genetic improvement programs. Better physiological quality can be achieved through the use of improved procedures for seed collection, processing, storage, distribution and records management.

Research is needed to identify the best seed collection times, pre-storage treatments, and storage regimes for many tropical tree species. Azadirachta indica, an important exotic, produces seed which retains viability for only 4 weeks, limiting its use in agroforestry programs. Methods need to be found to prolong seed viability of this and other important species (i.e., Swietenia macrophylla, Swietenia mahogani, Simarouba glauca). Standardized procedures need to be developed for the central pre-processing of seed that can then be returned to storage without significant loss of long-term viability.

Pre-sowing hot or boiling water treatments used to break seed coat dormancy tend to produce inconsistent results, often because of physiological differences between seed lots of the same species and variability of seed treatments (i.e., temperature, treatment duration, etc). (Willan, 1985). Seed-born plant diseases (i.e., Cercospora Leaf Blight on Cassia siamea) and methods of sterilization of infected seed also should be investigated.

## MICROSYMBIANTS

Nitrogen-fixing trees account for twenty five percent (25%) of all trees produced in the AOP, with the majority being leguminous. All nitrogen-fixers are inoculated with the appropriate strain of *Rhizobium*, produced in a Haitian laboratory from NifTAL (Nitrogen Fixation by Tropical Agricultural Legumes, Paia, Hawaii) cultures, or with crude inoculant produced from crushed *Frankia* nodules (for Casuarina species). In addition, pines are inoculated with imported *Pisolithus tinctorius* or a locally collected ectomycorrhizae.

Methods of collecting strains of Rhizobia and Frankia, and of testing these strains for infectiveness, effectiveness, ability to cross-inoculate, and adaptability to specific environmental conditions are research topics of major importance for tropical agroforestry programs that use nitrogen-fixing trees. The identification of superior microbial strains as well as a formal matching of particular strains to particular species and sites would be highly useful results.

Determination of the longevity and competitiveness of selected rhizobial strains in tropical soils, as well as the examination of native rhizobial populations and ecology on severely degraded soils, would be of great value to field practitioners. Methodologies to produce Frankia on a commercial scale are also needed. Procedures to inoculate tree seedlings with microsymbiants have been investigated in Haiti (Reid, 1989b). Further work needs to be done to see what benefits, if any, are accrued by early inoculation in the nursery. Development of microsymbiant strains resistant to pesticides (especially fungicides) commonly used in the nursery is another important and relevant research area.

Pinus occidentalis, a valuable tropical pine endemic to the island of Hispaniola, spans a broad ecological amplitude, from 200 - 3000 meters altitude, and from acid to calcareous soils. Due to its wide adaptability, especially on calcareous soils, this tree and its associated mycorrhizal symbionts may be of significant value to reforestation projects worldwide. To date, inoculation with ectomycorrhizae in the nursery has been achieved by mixing pine soil into the potting medium; the particular mycorrhizal strains best adapted to calcareous, high pH soils have never been investigated. Inoculation with select strains of vesicular-arbuscular mycorrhizae may also significantly improve growth in tropical hardwoods, especially when seedlings are planted on the severely degraded, impoverished sites commonly found in the tropics.

## STOCK QUALITY

Numerous criteria have been developed to determine planting stock quality in the temperate zone. Morphological and physiological characteristics have been correlated with seedling survival and growth, aiding nursery managers and their clients determine seedling quality.

No such criteria exist for the vast majority of tree species produced in tropical agroforestry nurseries. Even the most basic correlations between simple morphological characteristics such as root collar diameter and post-planting survival and growth are non-existent. Thus, other than a completely subjective decision that a seedling "looks good", tropical nursery managers have no way to judge stock quality. Research is clearly required to resolve this situation.

## CULTURAL PROCEDURES

Methodologies developed in the temperate zone to harden—off seedlings are usually directed toward cold hardiness, an orientation of no practical use in the tropics. There is no well-established method to harden-off a tree seedling in a tropical nursery, or for that matter, to determine whether a seedling should be hardened-off. In the absence of basic information, the most commonly used method to prepare a seedling for outplanting is via water stress and occasionally nutrient stress, applied for a period of time prior to shipping. The actual effects of these stresses on the physiological condition of the seedling and on post-planting survival and growth are unknown.

Due to the calcareous nature of the bedrock underlying most of Haiti, the majority of nurseries use irrigation water of pH 7-8 or more, resulting in phosphorus and micronutrient deficiencies in planting stock. Nurseries usually have little opportunity to control the pH of the water due to limited infrastructure and equipment. Thus, specific fertilization regimes need to be developed for these particular conditions. However, specific nutritional requirements for most species have not been determined. The current practice of using 20-20-20 for all seedlings leads to overfertilization and excessive growth in some species and underfertilization and nutrient deficiencies in others.

Finally, integrated pest management in tropical nurseries is an important and potentially fruitful area for research. Many insect pests are already being successfully controlled via the use of pesticides found in plants growing locally; Azadirachta indica (Neem), Nicotiana tabacum (Tobacco), Capsicum fritescens (Chili Pepper), Annona muricata (Corrosol) and Annona squamosa (Cachiman) (Josiah, 1989). Development of effective, natural fungicides derived from local plant materials are definitely needed. Soil pathogen inhibition via natural microbial competition also deserves investigation.

## SPECIES SELECTION

Generally, AOP nurseries are demand-driven, producing seedlings of species which the farmers want. However, farmers occasionally want valuable hardwood species (i.e., Cedrella odorata) not well adapted to the ecological conditions existing in their region or farms. Effective screening of the appropriate species for particular ecological conditions requires that considerable resources be expended on species trials. Multiple provenances of each species should be tested on a variety of sites. All too often, however, a single provenance of a species is tested on one site and the decision to accept or reject the species program-wide is made without examining other provenances or environmental conditions.

## CONCLUSIONS

In agroforestry one cannot isolate the nursery and its technical needs from the larger planting, farming and social systems it serves. A holistic approach balancing technical and social issues must be taken if improvements in outplanting survival and growth are to be achieved. Nurseryperson training materials specifically created for developing, tropical countries can be effective tools for integrating modern techniques with traditional practices (Josiah, 1989). In addition to the research needs detailed in this paper, further work must address issues such as development of transport and distribution procedures which minimize seedling stress and shock, and improvement of extension methods and messages that improve post-planting care and survival. Additionally, species selections must be properly screened, and must be matched to the particular site conditions. Finally, the trees distributed must be of the species the farmer wants.

Considering the massive reforestation needs existing in heavily populated tropical countries, nurseries alone cannot meet the demand for trees. While nurseries are important and form the backbone of many agroforestry programs in the tropics, there is a strong trend toward complementing central nursery production with farmer-implemented re- forestation strategies, including living hedgerows, direct seeding, "stump" plantings, and small, local plastic mini—sac nurseries. Such innovative approaches must be implemented if sustainable agro-silvopastoral systems are to be preserved or established.

Nurseries, however, serve another role in developing countries besides the obvious function of tree production. Trees produced in nurseries are a valuable means of environmental education, showing rural dwellers in a tangible, visible manner the economic and environmental values of trees in their farming systems. Once a certain level of awareness and sophistication is achieved, other strategies such as those listed above can be successfully introduced.

Nurseries in tropical developing countries are currently producing tens of millions of trees every year, mostly using antiquated methodologies and techniques. Tropical nursery managers have not not had the benefit of research specifically focused on their particular and unique problems. With so much to learn, large gains in seedling quality, survival and growth can probably be achieved with relatively modest research efforts. Considering the growing awareness of the importance of tropical biological systems to the overall health of the global ecosystem, it is obvious that these research needs must be addressed by the combined efforts of both developing and developed countries alike.

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# RESEARCH NEEDED IN THE NEXT TWO DECADES TO SUPPORT FOREST TREE NURSERY PRODUCTION IN THE NEXT CENTURY

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## SUMMARY

Research needed in temperate zone industrial nations will concentrate on (1) testing for stock quality, (2) matching microsite and seedling capability, (3) automation and mechanization of nursery practices, and (4) environmental safety. Research needed in developing tropical countries must (1) determine the propagation characteristics, genetics, and provenance adaptability of a large number of tree species and (2) develop nursery practices adapted to the tree species to be grown and to the local economy and culture.

Keywords: Nursery operations, research needs

## INTRODUCTION

To judge what reforestation research will be needed, we must first look at current trends and emerging problems. Let us start by placing tree nurseries in the broader perspective of forest establishment. The objective of forest establishment is to achieve adequate stocking of vigorous seedlings of the desired species. The nursery is not an end in itself, but represents just one phase of the reforestation process.

It must be recognized that tree planting affects the genetic composition of the forest very differently from natural regeneration. In the latter, only a tiny fraction of the seed that falls on a site becomes established trees. Genetic selection is intense and occurs on the microsite where the individual tree will grow to maturity. The survivors are by definition well adapted. In nursery production and tree planting, however, natural selection is minimized. The goal is to grow a tree from every seed in the nursery, and for every planted tree to survive and grow in the field. That means regeneration foresters must do the selecting. We need to (1) know the capabilities of the provenances we are raising, (2) know the characteristics of the microsites where they will grow, and (3) match the two. How nurseries respond to these needs and what research is needed to support their efforts will depend on where they are and the stage of development of the country.

## TEMPERATE ZONE INDUSTRIAL NATIONS

Consider first the situation of industrial nations of the temperate zone. The direction is toward high-technology, capital-intensive mechanization and automation to save labor and achieve more precise control. I see four major trends, each of which will require research and development.

### Testing for Stock Quality

For decades seedlings have been graded morphologically for characteristics shown to be useful indicators of potential to survive and grow when outplanted. In recent years this grading has been supplemented by physiological tests which not only promise better guidance than morphological criteria, but will eventually form the basis for describing the capabilities of provenances as mentioned above (Duryea 1985). Some of the tests in current use are cold hardiness, root growth potential, water potential, foliar nutrient analysis, and chlorophyll fluorescence. We are still learning how much these tests can tell us, but their value is already established. Isoenzyme analysis is currently used to confirm the identity of seed lots, but in the future it may tell us about the physiological capabilities of seedlings. Nurseries of the future will have their own testing laboratories and rely less on outside help.

### Matching Microsite and Seedling Capability

Although currently not the responsibility of the nursery, outplanting microsites will need to be characterized in much greater detail than ever before. Regeneration silviculturists will need to progress from observation and habitat classification (i.e., using existing vegetation to infer microclimate) to measurements that will quantify temperature, water relations, nutrient status, solar radiation, pests, and competition. This is the information needed to match the provenances to the site.

However, knowing what is there now is not enough. We must be able to predict microsite climate for the next rotation, which may be anywhere from 20 to 120 years, and we now have good reason to believe that it will not be the same as the last rotation due to the "greenhouse effect." (Schneider 1989). The high latitudes are expected to be impacted more than the tropics, but beyond that we know little. Regional models of future climate are still conflicting and fuzzy, and local models are probably meaningless. In addition, planting microsites may be changing with respect to soil structure, chemistry, and water relations as a result of the growth and treatment of present and previous rotations. Thus, predicting future site quality may be difficult.

## Automation and Mechanization

Mechanization has been ongoing for 60 years, but with the introduction of computer control we can expect to achieve new levels of speed and precision in the full range of seeding, tillage, and lifting equipment, and seedling grading and sorting (Rigney and Kranzler 1988). Computers now maintain and record environmental conditions in greenhouse nurseries and automatically control irrigation according to need in both bare-root and container nurseries. Computers track inventories of seed and seedlings (Pelchat 1988), and with the introduction of bar codes, inventories, sorting, and shipping will become even more automated. This automation will assume increased importance as nurseries deal with more and smaller seed lots corresponding to increasingly fine tuned adaptation to field microsites.

As mechanical handling of seedlings increases, it will be necessary to monitor the effects on seedlings. The machines must handle seedlings gently. For example, I recall a device built many years ago to singulate conifer seedlings for transplanting. Bundles of freshly lifted conifer seedlings with tangled roots were fed through a succession of gripping belts, each belt moving faster than the previous one, and when the seedlings came flying off the far end, they were indeed separated. However, a year later many of them were dead because of damage to the cambium at the root collar where the belts had gripped the seedling. (Rather than scrap a perfectly good machine, another use was found. Populus cuttings run through the belts rooted in several places along the stem instead of just the bottom surface, yielding a more vigorously rooted cutting.)

## Environmental Safety

Pesticides have always been an important tool to help nurseries produce the desired quality and quantity of plants reliably. However, in recent years there has been a rapid turnover in what pesticides are available or permitted, as undesirable side effects of individual chemicals are discovered. The requirements for bringing new pesticides onto the market are increasingly stringent, time-consuming, and expensive. Manufacturers are increasingly loath to do the research and testing necessary for any use that does not promise a large volume of sales, which forest nurseries do not. There is no end in sight to this trend. That means (1) few, if any, new products will be developed that are intended specifically for forest tree nurseries, and (2) the forestry community will have to do much of its own research to adapt existing products to tree nurseries.

Nurseries have been identified as potential sources of pollution, and will have to learn to confine potential pollutants within their own boundaries. Potential pollutants include air- and water-borne soil, air-borne volatile chemicals, and pesticides and fertilizer entering the groundwater or surface runoff.

As output per worker rises, and as training and skill requirements rise, the cost of accidents and sickness also rises. This will promote increasing emphasis on worker safety (Wallersteiner 1988). Machines are already built with protection against obvious opportunities for injury, but automation will further remove workers from hazardous situations. However, when it comes to preventing accidents, no amount of mechanical devices can replace well trained and alert workers.

## TROPICAL THIRD WORLD NATIONS

The situation with tropical third world countries is quite different. In many places deforestation is proceeding rapidly and is leading to land degradation and subsequent intensification of rural problems. Thus, there is an emerging need for increased nursery production to counteract deforestation and reclaim damaged land (Evans 1984, Wiersum 1984).

These countries tend to be short of capital, but have lots of cheap labor. Nurseries may tend to be small and reasonably close to planting sites because of the logistics of transporting nondormant trees over bad roads. Most, if not all, of the species to be planted have no true dormancy, and many are probably chill-sensitive. This means that extended storage is not feasible, and the best strategy is to lift, ship, and outplant in no more than a few days. Generally, container stock is favored over bare-root stock because the growing medium on the roots protects them during shipping and outplanting. Container grown seedlings generally do not suffer as much transplant shock or dieback (Walters 1981, 1983).

In contrast to the temperate zone, comparatively little is known about the genetics and physiology of many of the tree species grown in the tropics. In addition, poor countries lacking foreign exchange need to develop nursery systems that rely on locally produced materials to reduce the cost and dependence on imports. This means research must provide answers to some very basic problems that have long since been solved in temperate zone nurseries (Leigel and Venator 1987).

Consider first the container itself. Many developing countries still use plastic sacks, which are monetarily cheap but biologically expensive. Their unribbed circular shape encourages a tangled root system likely to impede field establishment and growth, and make the tree susceptible to windthrow. What is needed is a cheap, durable container that incorporates everything we know about producing favorable root system configurations.[1]

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[1] Tinus, R.W., 1989. Unpublished report to Pan American Development Foundation. Washington, D.C.

In the temperate zone most growing regimes have been developed around peat-vermiculite growing media, because these materials are readily available and have favorable and consistent physical and chemical characteristics. In the tropics, however, peat and vermiculite are expensive, because they must be shipped long distances from their origin. Although there are abundant supplies of organic materials that may be suitable for composting, the products of composting are not the same as peat. Compost may have different fiber characteristics, possibly toxic compounds, and probably an abundance of plant mineral nutrients. Research will be needed to develop suitable recipes for proper preparation of local materials, and to determine the chemical and physical characteristics of the product. Research will also be needed to prescribe suitable growing schedules, especially with regard to fertilization and irrigation, that take advantage of, or cope with, the properties of the locally produced growing media (Dalzell et al. 1987).

The hardening process for tropical species is different from temperate zone species, because the former are probably not photoperiod-sensitive and show no true bud dormancy. In temperate zone species, short photoperiod, nitrogen reduction, and water stress are used to initiate dormancy. After dormancy becomes irreversible, the seedlings are again kept well watered, and probably need not be on low N, although it is standard practice to do so. By the time chilling requirements for budbreak have been met, continued quiescence is usually maintained by low temperature. In contrast, in tropical species cessation of growth is externally imposed and maintained by nutrient and drought stress.

During hardening, top and root growth cease, and there is a visible increase in stem lignification and leaf cuticularization. Although these characteristics should help increase survival when seedlings are outplanted, I know of little or no research that demonstrates this to be true. It would be useful to determine what, if any, benefits hardening has, because the hardening process has risks of its own. During droughting the margin for error between stopping growth and damage to the seedling is poorly known.

In the tropics there are a large number of species to choose from, and except for a few, comparatively little is known about their propagation characteristics, genetics, and the adaptability of different provenances. We need to learn more about the ecophysiology of tropical species before we can propagate them successfully. Little is known about production cycles, dormancy, and storage of most tropical species, and even less about the importance of seed sources. Many times exotics are grown and planted because that is the only source of good seed (Zobel et al. 1987). Fortunately, results of provenance testing in the tropics are available in 3 to 7 years because of rapid growth rates. As this information becomes available, tropical nurseries will have to deal with increased numbers of seed lots within species, something temperate zone nurseries are already experiencing.

According to current predictions, the tropics should be minimally impacted by the expected global climate change, and thus current climate is a better predictor of future climate than at higher latitudes (Schneider 1989). This is fortunate, because it means that countries least able to cope with climate change are likely to experience the least change.

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# TECHNIQUES FOR TREE ESTABLISHMENT IN DRY ZONES - EXPERIMENTS AND PRELIMINARY RESULTS

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## ABSTRACT

Water deficiency and water stress in low rainfall areas and browsing by domestic and wild animals are the most common causes of high mortality in newly planted trees, particularly in the tropics.

During the period April 1984 to December 1989, two field experiments were carried out. The first aimed at improving survival of tree seedlings by introducing a moisture-conserving planting technique; the second attempted to reduce damage from excessive browsing.

The moisture-conserving **open-pit sunken planting** was compared with commonly practiced ground level planting. In an area with deep medium loamy soil and a mean annual bimodal rainfall of 720 mm two different species were used for the comparative study. One, Acacia mellifera, was indigenous and well adapted to the environmental conditions of the experimental site; the other, Leucaena leucocephala, was an exotic and at the margin of its optimum environmental requirements. The open pits acted as litter traps, building up mulch, and the wind speed and radiation at the soil surface around the root collar were reduced, which led to reduced evapotranspiration. In addition water retention was improved. As a result, 18 months after establishment, mortality of L. leucocephala seedlings planted in open pits was about half that of seedlings planted at ground level, and average shoot length growth was more than double. With Acacia mellifera, the positive effect of open pit sunken planting was even greater. Shoot length growth of seedlings in open pits was almost triple that of seedlings planted at ground level, and biomass production was nearly 80% higher. Comparative biomass assessment of L. leucocephala is currently in progress.

In another set of experiments five locally available materials were tested for their capacity to prevent browsing. These were sisal fibre, fibre from Kapok pods, fruit extract from Solanum spp., clipped sheep wool and crushed seeds of Datura stramonium. The materials were applied to L. leucocephala seedlings, which were then exposed to browsing by goats. Clipped sheep wool and Kapok fibre proved very effective, but the other materials tended to retard, but not prevent, browsing.

# STAND ESTABLISHMENT AND DEVELOPMENT: TRADITIONAL AND NEW CHALLENGES AND ISSUES IN TECHNIQUES, WORK STUDIES AND DATA NEEDS

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## SUMMARY

Recognizing the major developments in new technologies in growing and managing forests, an attempt is made to identify the effects of establishment and stand tending actions on stand and forest timber and non-timber attributes. A listing is provided of specific challenges for research at the tree, stand and forest level in the fields of biometrics, ecology, silviculture and sociology. It is concluded that there are exciting new opportunities for research in establishment and tending.

## INTRODUCTION

Research needs in stand development: techniques, work studies and methods development. This title tends to bring to mind the image of a researcher standing in the forest with a stop watch timing a new piece of silviculture equipment. Upon reflection, however, it is a dangerous trap to think in this traditional way. Forest research workers in the U.S. and Canada have got into trouble thinking in such a narrow way.

As we move into the 21st century, forest researchers find themselves being asked new questions about stand establishment and the techniques they use to change stand development. The answers to the new questions are not readily forthcoming because they relate not just to stand timber (growth, yield, dimension and quality), but social, ecological, managerial, financial and environmental issues. Foresters have been accused of not knowing what they are doing when clearly they thought they did. Is it just a different preception of old tending practices or are they really valid questions? Did we ask these questions before and do the required research? The answers are usually no. We did not. At least, not to in the way we should have done to provide credible answers we need today. We were too narrowly focussed on timber and money, and not enough on people and the environment. The research challenge is great because unless we provide credible answers quickly, current worshipers of naturalistic doctorines of no human intervention in stand dynamics may prevent many silviculture practices. Also, the social and community problems in many locations require that these receive high priority in planning establishment and tending. This paper attempts to outline the challenges in establishment and tending: Some are traditional, almost classical for IUFRO congress presentations; others are new challenges, even more complex and difficult than the old ones.

## THE EFFECTS OF STAND TREATMENT

The challenges of stand tending research cover many issues and fields of research. They are complicated and interrelated, so I have used tables to help clarify them. Table 1 shows the effects of stand treatments on some stand timber and non-timber attributes. A tick indicates that the stand attribute is changed by the tending action. All five classes of tending actions tend to be interconnected. While for some well researched forest types, the magnitude and direction of the changes are reasonably well understood; for many timber types, they are not - even for timber attributes. Even well researched actions, like site preparation in northern conifer forests, still have a lot of unknowns.

For the non-timber values, the technical effects are less well understood and less well researched, yet it is about these values that many questions are asked today by environmentalists. The concepts and principles behind the changes are well recognized, but specific quantitative and qualitative information is often lacking.

A major challenge for research in stand tending is that of continually changing stand management objectives. Stand dynamics can be slow, often slower than changing priorities in land and markets and utilization technology. The danger of foreclosing options in achieving stand level objectives has traditionally led foresters to conservative tending strategies.

One of the challenges lies, thus, in the forecasting and planning of the effects of changes in stand attributes on the whole structure of the forests and its timber and nontimber outputs. This interface between stand level crop planning technology and forest-level multiple-use strategies is most complex. It has also been revolutionized by computer technology in the areas of inventory, growth and yield and Geographic Information Systems.

It is not enough for the forester to be only concerned with the intricacies of regeneration and successful stand establishment for timber. The forester must clearly plan and forecast the outcomes of all the tending practices that will be used in the life of the stand. This planning is embodied in the silviculture prescription, prepared before any forest is cut. The prescription must be legally and environmentally defensible. It must also be shown to conform with the stand-management objective and the multiple-use objectives of forest management.

In both the U.S. and Canada, Silviculture Institutes have been set up to provide graduate-level education to practicing silviculturists. The objective is to improve the silviculture prescriptions. As an instructor in such an institute, I have found a severe lack of research on the ticks in Table 1. For some Canadian timber types, we have virtually no information.

## SPECIFIC RESEARCH CHALLENGES

Table 2 attempts to provide a "shopping list" of research needs for stand establishment and tending. The ticked items indicate a need for research; a double tick, a pressing need. The distinction is made between tree level, stand-level and whole forest-level studies. Traditionally, much stand establishment work has been at the tree level, i.e. ensuring indiviudal trees grow well.

However, decisions which are made to actually carry out large-scale establishment and tending projects require a good understanding of stand and forest-level effects. This is particularly true when environmental and fiscal accountability are required.

Recently, there has been an almost explosive development of new technologies in stand establishment and tending. New machines, new chemicals, new propogation procedures, better use of fire, sophistication in stand software yield simulation, improved inventory techniques and new products and markets. All these technologies have created new and genuinely exciting opportunities for research in establishment and tending. However, the use of the new technologies has raised serious environmental questions. As some silviculture practices emulate intensive agronomic practices, then questions naturally arise about their environmental appropriateness.

Naturalistic doctrines in silviculture practice are now finding favour again in North America.

Table 1. The effects of stand treatments on timber and non-timber stand attributes little effect (√ has effect, x has no or little effect).

| | Stand Treatment Actions | | | | |
|---|---|---|---|---|---|
| Stand and Forest Attributes | Regeneration Actions | Spacing and Thinning | Tree Improvement | Fertilization and Drainage | Pruning |
| Stand o Timber | | | | | |
| Volume | √ | √ | √ | √ | √ |
| Dimension | √ | √ | X | √ | √ |
| Quality | √ | √ | √ | X | √ |
| o Non Timber | | | | | |
| Wildlife habitat | √ | √ | X | √ | √ |
| Sustained fertility | √ | X | X | √ | X |
| Recreation values | √ | √ | X | X | X |
| Landscape values | √ | √ | X | X | √ |
| Forest o Timber | | | | | |
| Accelerated operability of young age classes | √ | √√ | X | √√ | X |
| Allowable Cut Effect possibilities | √ | √√ | X | √√ | X |
| Reduction in biological risks of loss of forest | √√ | √ | √ | X | X |
| o Non Timber | | | | | |
| Improved biological Diversity | √√ | X | X | X | X |
| Wilderness preservation (by growing more wood in commercial forests) | √√ | √√ | √ | √ | √ |
| Job Creation, community stability | √√ | √ | √ | X | √√ |

Table 2. Specific Challenges for Stand Establishment and Stand Tending Research (✓ needed, X not needed)

| | Area of Research | | |
|---|---|---|---|
| | Technique Development | Work Studies | Stand level data needed |
| 1. Biometric: stand level | | | |
| Height growth curves | ✓ | X | ✓✓ |
| Yield volume simulation | ✓ | X | ✓✓ |
| Yield grade and value simulation | ✓ | X | ✓✓ |
| Self thinning, stand density management diagrams | ✓ | X | ✓✓ |
| Old-growth breakup and risk of loss, advance growth development | ✓✓ | X | ✓✓ |
| 2. Synecological: stand and forest level succession trends and site index determination for site types | ✓ | X | ✓✓ |
| Linkage of animal habitat needs to site types and tended stand structures | | | |
| Parallelism between stand development following natural versus man-made disturbances | ✓✓ | X | ✓ |
| 3. Autecological: tree level environment x genotype interactions, especially nutritional response | ✓✓ | X | ✓ |
| Clonal propogations and biotechnology effects on stand development | ✓ | X | ✓ |
| Direct Seeding and scarification to produce acceptable seed beds | ✓✓ | ✓ | X |
| Use of fire, machines and chemicals for site preparation | ✓✓ | ✓ | ✓ |
| Planting stock quality and vigour | ✓ | X | X |
| 4. Silvicultural: stand level modification of harvesting systems to preserve or enhance natural regeneration | ✓✓ | ✓ | X |
| Use of fire, machines and chemicals for vegetation management | ✓✓ | ✓ | ✓ |
| Continued attempts to harvest trees lost by mortality | ✓✓ | ✓ | X |
| Development of better diagnostic procedures for fertilizer use | ✓✓ | X | X |

Table 2. Continued

| | Area of Research | | |
|---|---|---|---|
| | Technique Development | Work Studies | Stand level data needed |
| Root diseases: diagnosis, consequences and environmentally sound treatment methods | √√ | √ | X |
| 5. Managerial/economic: forest level<br>Improved inventory and Geographic Information System implementation | √√ | X | √ |
| Forest level simulation of flows of timber and non-timber benefits of stand tending | √√ | √ | X |
| Improved silviculture decision making, audit and control systems | √√ | √ | X |
| Preparation of environmental impact assessment of the effects of establishment and tending | √√ | X | √ |
| 6. Sociological: forest level<br>effects of and need for stand tending to meet community needs | √√ | X | X |
| Work environment, health and safety studies | √ | √√ | X |

# BASIC TIME CONCEPTS FOR INTERNATIONAL COMPARISONS OF TIME STUDY REPORTS.

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## FOREWORD

At the symposium of IUFRO WP 3.04.02 (Work Study, Payment and Labour Productivity) in Thessaloniki 1988, a group was appointed to prepare a proposal for an international forest work study nomenclature. This paper contains a proposal of basic time concepts to be used for international comparisons of time study reports. The group preparing the proposal had the following composition:

**Prof. Reidar Skaar** (chairman), Norwegian Forest Research Institute, Ås, Norway
**Prof. Sigfried Häberle**, University of Göttingen, Göttingen-Weende, Federal Rep. of Germany
**Prof. Jeremy Rickards**, University of New Brunswick, Fredericton, N.B., Canada
**Mr. Karl Apel**, Forest Service of Hessen, Weilburg, Federal Rep. of Germany
**Mr. Rolf Björheden** (working secretary), Sw. Univ. of Agric. Sc., Garpenberg, Sweden

I would like to thank the members for the effort they have made to bring this work to conclusion.

## SUMMARY

In this paper, a proposal of a system of basic time concepts is presented. The lacking uniformity of time concepts was identified by the group preparing this proposal as the single most important obstacle when trying to make international comparisons of time study reports. The aim of the proposal is to set standards for scientific presentations so that international comparisons and analyses of results are simplified. The proposal is *not* aimed at defining a terminology for the practical time study, nor does it contain suggestions on what methods to use (or not to use). It simply contains a number of **basic concepts for time measurements of work** that should always serve as a basis for any study claiming international significance.

It is the suggestion of the 'terminology team' that study results should either be published using the terms defined by the proposal or in such a way that a transformation into the proposed concepts is possible.

## INTRODUCTION

**Work science** is the part of science dealing with technical, psycho-social and organizational development of work. Work science utilizes the theories and the knowledge gained by other sciences to the extent they are related to work. One of the most important means of work science is work study. Both work science and work study are very much oriented towards the application of the produced knowledge. It is important to remember that, from a scientific point of view, work science and its subdisciplines should be free of subjective values although the different work study techniques - as method study and work measurment - almost by definition are employed to "improve" the utilization of human and material resources. Work science performs critical examination of existing and proposed ways of doing work based on objective and unbiased observations and prognoses. The subsequent choices and decisions of "best" alternatives, "juste" piece rates etc. are political or managerial issues and has little to do with science as such.

**Work measurement** may be defined as measurment of the input of human and material resources into production and/or the output of the production process. The measured variables are the consumption of resources and the products of work. For man at work, time consumption, movements and working motions, physical load and psychic load may be measured. For machines and equipment the measurment may regard time consumption, movements and working motions, wear and energy consumption. In addition, the operate (work object, workpiece), the production environment and the quantity and quality of products are described.

**Time study** is one of the most common practices of work measurment. It is used world wide, in most types of production to determine the input of time in the production process. In forestry, results from time study have been used to set "juste" piece rates and, most important, to rationalize production. When time study data are used to rationalize production it is usually applied with one or several of the following four goals:

1. Improvement of work organization and planning
2. Control and following up of operations
3. Improvement and comparisons of working methods, tools and machinery
4. To create data for performance and cost calculations

Time is thus regarded as a resource and the measurment of time is used to establish the productivity ratio as ***product output/time input*** for a given production system. Qualitative differences of studied production systems are often translated as varying costs per time unit. The time cost is commonly based on the "market prize" of the studied system, in its turn a resultant of demand and supply interactions of a "free market".

The use of time costs is, in reality, an effort to estimate, in a common measure, the total input of resources per time unit into the production process. It is based on the assumption that the "market prize" reflects the objective utility of a certain combination of resources. If this assumption is correct, the combination of time consumption and cost per time unit will be the ultimate measure when comparing alternative production systems. The shortcomings of this measure occurs when we wish to compare data from segregated markets. Because of market dissimilarities, the relative cost of different resources will also differ and direct comparisons will be of little use. Further, the prizing behaviour on the real market deviate from the rather mechanistic models proposed by classical economy, markets will change with time and the "freedom" of the market is commonly restricted. Thus, the use of cost per produced unit as a comparative measure is only usable within the same market or, maybe, between similar markets and only for data originating from the same period of time. We may conclude that the only measures that are possible to use when comparing production systems operating on different markets are those that may be objectively measured, such as time and energy input per produce output.

## OBJECTIVE

The internationalization of trade, enterprise and research has increased the need for international information flows, not least in the forestry sector. In this context, the lack of an international standard for presenting results has become a major obstacle. If a free and meaningful flow of information is to be obtained, it is essential that a set of standardized terms is agreed upon.

An analysis made by the group indicated that the major obstacle when making international comparisons is not terminological or methodological. The confusion was rather a result of the great variety of measures and units used for the presentation of study results. The standardization of operate measures, as the volume of wood etc. seemed to be a question primarily concerning other sections of IUFRO. Therefore, the group chose, as a first step, to create a simple set of time concepts which could serve as a basis for an internationally agreed way of comparing time study reports. First of all, it was decided in what areas these terms were to be used. Three levels were identified:

Firstly
The nomenclature should enable international and - maybe also - interdisciplinary comparisons of data and results. This was considered to be the most important demand.

Secondly
The nomenclature should be adequate for scientific studies on the national level. By this we mean that terms and definitions given by the new nomenclature should be usable when presenting results. It has not been the purpose to present a terminology to be used in practical studies conducted in the respective countries.

Thirdly
The nomenclature should contain terms and definitions usable in the normal operations of forestry companies, forest owners associations etc.

Further, the set of concepts should be applicable under different external conditions as well as different degrees of technical development, be easy to adapt in practical forest operations and as coordinated with established standards 'outside' forestry as possible.

# A PROPOSAL OF BASIC TIME CONCEPTS

After effecting a compromise of the partially conflicting demands outlined in the previous sections, the terminology group agreed that the proposal of a forest time study nomenclature should be held extremely simple. It should list only some basic time concepts and definitions. The varying need for more detailed definitions that is bound to occur on the operational level and for specific research projects may then be decided by the individual company, research organization or research officer. *The main thing is that all such further developments of the IUFRO-nomenclature must be defined in such a way that it is possible to transform any time concepts used for a specific purpose into the basic terms defined in the IUFRO-nomenclature*. This means that all publications not directly using the proposed terms should contain a guide providing the information needed to make the transformation into the terms of the IUFRO-nomenclature.

The structure of the proposed basic time concepts is shown in figure 1, below.

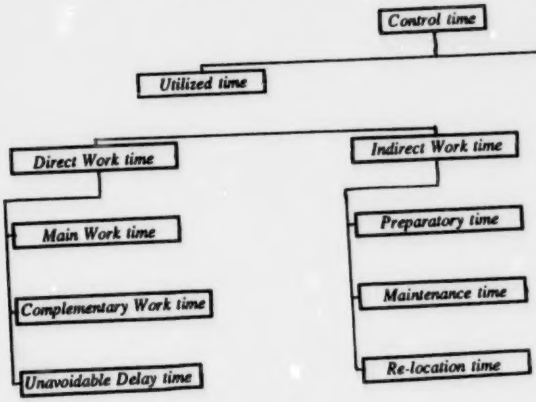

Figure 1. The structure of the basic time concepts.

## Definitions of the Basic Time Concepts

**Control time (C t)**
Control time denotes the time elapsed between two readings of a clock. Thus it consists of the absolute, calendaric time (all available time of a period, e. g. 24 calendar hours/day) and is used, in the suggested system, as a control time on which utilization and performance measures of systems, machines and components are based, directly or indirectly.

**Unutilized time (Un t)**
Unutilized time is the part of control time that is not used for the completion of a specified work task.

**Utilized time (U t)**
Utilized time is the part of control time that a production system or part of a production system is occupied, directly or indirectly to complete a specified work task.

**Direct Work time (D W t)**
Direct work time is the portion of utilized time that directly adds to the completion of a certain work task.

**Main Work time (M W t)**
Main work time is the part of the Direct work time that changes the work object with regard to its form, position and state within the definition of the work task.

**Complementary Work time (C W t)**
Complementary work time is the part of the Direct work time that does not change the work object with regard to its form, position or state but is needed to complete the work task.

**Unavoidable delay time (U D t)**
An inevitable interruption due to the nature of the work cycle, the design and choice of tools, machinery, organization, etc.

**Indirect Work time (I W t)**
Indirect work time is the part of utilized time that does not directly add to the completion of the work task, but is performed in order to support it.

**Preparatory time (P t)**
The time used for the preparation of machines, equipment and the conditions of the work place when beginning and after finishing a work task.

**Maintenance time (M t)**
The purpose of these interruptions are to maintain the working capacity of men, machines and other parts of the production system. For tools and machines **M t** may be divided into **Repair time (Rep t)** denoting inevitable, non-cyclic interruptions that are needed to repair damaged components and **Service time (S t)**, i. e. principally cyclic interruptions that occur in order to compensate the succesive degradation of tools and machinery employed at work.

**Re-location time (R t)**
The portion of utilized time that is used in order to transport men, machines, equipment etc. so that the work task may be completed.

**Examples of Machine and System Performance Measures**

**Degree of utilization:** (U t/C t)*100

**Effective time factor:** (D W t-U D t)/U t

**Productive time factor:** D W t/U t

**Preparation time factor:** P t/D W t

**Service factor:** Service time/D W t

**Repair factor:** Repair time/D W t

**Maintenance factor:** M t/D W t

**General Definitions**

**Work task** - a clearly defined and limited amount of work performed in order to change the work object form a clearly defined original state into a fixed end state

**Work element** - a sub-division of a work task that is defined and given limits

**Work cycle** - a sequence of work elements repeated for every work object or work piece. A work cycle of higher order may consist of a number of work cycles of lower order

**Work object** - the physical form that is changed within the definition of the work task. The work object may consist of several work pieces.

**Work piece** - a sub-division of the work object characterized by repetitive or cyclic properties.

# AN EXAMPLE OF THE USE OF THE BASIC TIME CONCEPTS

## 1. Description

### 1.1 Work object

A 30 year old spruce stand with an annual yield of 11.5 $m^3$ stem volume o.b. The stand has 2000 st/ha with an average diameter of 14 cm and a basal area of 30 $m^2$/ha.

### 1.2 Work task

To thin the stand described in 1.1. The basal area should be reduced to 22 $m^2$/ha by thinning "from below" which means that about 1000 stems (~ 50 $m^3$) are to be removed. The strip road width is not to exceed 4 m and the strip road distance should be ~ 25 m.

### 1.3 Production system

The production system consists of two workers and a pulp chip harvester with a felling head ($d_{max}$ 30 cm) mounted on a 9 m crane, a processing aggregate which limbs banks and chips trees in a continuous process and a bin (16 $m^3$) for transportation of the produced pulp chips.

### 1.4 Work organization

Both workers have a working time of 8 hrs a day, excluding a lunch break of one hour. They are working on a job rotation schedule with overlapping shifts where worker A starts at 6.00 in the morning, runs the chip harvester until 9.00 when worker B comes to work and drives the machine until 12.00. During his ground-shift (from 9.00 to 12.00), worker A fells the trees that cannot be reached by the harvester from the strip road. These trees can then be reached and pulled to the processing unit with the crane. From 12.00 to 15.00 when his working day ends worker A operates the machine again. During this period worker B has a similar ground shift as worker A.

From 15.00 to 18.00 worker B has a final shift of operating the machine.

The workers leave the work place when their shifts are ended. For this specific thinning, worker A has to travel 20 minutes per day and worker B has to travel 40 minutes per day in order to get to and from the working place.

## 2. Application of the basic time concepts

### 2.1 Time study

We chose to do a time study along tree tracks:

A: The machine is studied
B: The mechanized felling is studied
C: The worker on ground shift is studied

The work task must be identified for A, B and C separately in order to apply the basic time concepts, since the choice of appropriate terms mainly depends on this definition.

### 2.1.1 Work tasks for the studied system components

A The task of the harvester unit is to select fell and process the trees in and near (< 9m) the strip road as well as pulling in and processing the trees manually filled between strip roads. When the chip bin is full, the harvester transports the chips to the landing and empties the bin into transport containers.

B The task of the felling head is to fell trees and to hold trees when they are pulled in and fed into the processing unit.

C The task of the worker on ground shift is to fell trees that cannot be reached by the harvester. Also he takes a lunch break during ground shift.

### 2.2 Harvester and felling head, application of basic time concepts

| Time | Activity | | Harvester | Felling Head |
|---|---|---|---|---|
| | - None | | Un t | Un t |
| | - Worker A driving to work[1] | | Un t | Un t |
| | - Moving harvester to stand | | Ut, IWt, Rt | Ut, IWt, Rt |
| | - Checking function of felling head | | Ut, IWt, Pt | Ut, IWt, Pt |
| | - Checking function of chipper | | Ut, IWt, Pt | Ut, DWt, UDt |
| | - Moving into stand | | Ut, DWt, CWt | Ut, DWt, UDt |
| | - Crane out | | Ut, DWt, MWt | Ut, DWt, UDt |
| | - Positioning | | Ut, DWt, MWt | Ut, DWt, MWt |
| | - Felling | | Ut, DWt, MWt | Ut, DWt, MWt |
| | - Pulling tree to machine | a | Ut, DWt, MWt | Ut, DWt, MWt |
| | - Feeding tree into chipper | b | Ut, DWT, MWt | Ut, DWt, MWt |
| | - Controlling start of chipping | c | Ut, DWt, MWt | Ut, DWt, UDt |
| | - *Cycle a repeated* | | | |
| | - Moving machine | | Ut, DWt, CWt | Ut, DWt, UDt |
| | - *Cycle b repeated* | | | |
| | - Transporting chips to landing | | Ut, DWt, MWt | Ut, DWt, UDt |
| | - Unloading | | Ut, DWt, MWt | Ut, DWt, UDt |
| | - *Cycle c repeated* | | | |
| | (- Worker B driving to work, Un t[1]) | | | |
| | - Changing operators | | Ut, DWt, UDt | Ut, DWt, UDt |
| | - Cycle c repeated | | Ut, DWt, UDt | Ut, DWt, UDt |
| | - Welding broken delimbing knife | | Ut, IWt, Mt (Rept) | Ut, DWt, UDt |
| | - Changing felling saw chain<br>etc. | | Ut, IWt, Mt (St) | Ut, DWt, Mt (St) |

1) Driving to and from work site is regarded as Unutilized time analogously to the corresponding transport of the machine from manufacturer to user

Worker on ground shift, application of basic time concepts

| Time | Activity | Worker A | Worker B |
|---|---|---|---|
| | - None | Un t | Un t |
| | - A driving to work | Un t | Un t |
| | - A operating harvester (see ex 1) | Ut, DWt, UDt | Un t |
| | - B driving to work | Ut, DWt, UDt | Un t |
| | - Changing operators | Ut, DWt, UDt | Ut, DWt, UDt |
| | - A fueling power saw (B op. harv.) | Ut, IWt, Pt | Ut, DWt, UDt |
| | - A walking into stand "- | Ut, DWt, CWt | Ut, DWT, UDt |
| | - A felling tree ] ] | Ut, DWt, MWt | Ut, DWt, UDt |
| | - A moving to next tree ]a | Ut, DWt, CWt | Ut, DWt, UDt |
| | - *Cycle a repeated...* b | | |
| | - A fueling power saw ] | Ut, IWt, Mt (St) | Ut, DWt, UDt |
| | - *Cycle b repeated...* | | |
| | - A taking lunch break[1] | Un t | |
| | - Changing operator on harvester | Ut, DWt, UDt | Ut, DWt, UDt |
| | - B walking into stand | Ut, DWt, UDt | Ut, DWt, CWt |
| | etc. | | |

Legend: ]work cycle

- start of activity

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[1] The lunch break is not considered to be a Maintenance time since the operator may use freely for any activity. As it has no direct connection with the work it should be regarded as Unutitilized time

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# FORMULAS: A FOREST MULTIRESOURCE ANALYSIS SYSTEM

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## SUMMARY

A system of models was developed to simulate multiresource outputs from southwestern forests and woodlands under alternative management regimes. The system has the capability of simulating tree growth and stand development including mortality; herbage yields and cow carrying capacity; water yield, soil loss; forest floor accumulation and decomposition including snags, logs, and debris; wildlife habitat; and near-view scenic quality. Management prescriptions are defined as one or more of the following activities: tree harvest, regeneration, salvage, fuelwood cutting, site preparation, prescribed burning, and range improvement. The system has been evaluated on the Coconino National Forest in Arizona and the Lincoln National Forest in New Mexico. The modular design of the system permits integration, testing, refinement, and evaluation of alternate resource projection models by land managers.

# FOREST OPERATIONS PLANNING AND CONTROL
## NEW SYSTEMS AND TECHNIQUES FOR MANAGERS

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## SUMMARY

The history of development of computer based systems to support forest operations planning and control procedures reflected advances in computer hardware and software and has been largely application driven. The result has been a myriad of systems each meeting a relatively minor series of related functions. These systems have resulted in overlap between each other often reflected in multiple input of the same data. The main benefits have been to enable non computer literate users to gain hands on experience and also to enable systems designers to gain a much wider understanding of individual applications within an organisational framework.

Future systems will be developed to meet corporate needs including those of the operational, tactical and strategic levels of management. Such systems will consist of many components, each addressing a particular range of activities and they will be fully linked together sharing and exchanging data as determined by overall business needs. New technologies such as geographic information systems will reflect new opportunities for implementation rather than new solutions to new applications.

## INTRODUCTION

Many organisations have been involved in the development of computer based systems to help support traditional forest operations planning processes. These systems have frequently only addressed relatively self contained aspects of planning procedures. Very few have taken a more extensive or integrated approach. During the 1960's and 1970's computer systems have been largely constrained by the hardware available. The advent of low cost, relatively powerful microcomputers in the late 1970's and 1980's provided opportunities to locate systems close to users. However again the systems were largely application specific.

This paper considers the needs of forest operations planning and control on a broader basis and describes how these needs can be met by fully integrated systems. These fully integrated systems include the needs of non operational levels of management - the tactical and strategic levels. The paper suggests that the development of planning systems should be based on an analysis of the full range of activities performed at all levels within organisations. The development of such systems is the result of an analysis of overall business needs. The paper draws on the authors experience in Great Britain where plantation forestry is the most significant form of management. The paper suggests that the development of planning systems should flow outward from a strategic view to individual applications rather than the other way around. Finally the paper identifies a number of areas where developing technologies will play a greater role in developing more flexible systems.

## TRADITIONAL APPROACHES TO SYSTEMS DEVELOPMENT

In the United Kingdom the use of computers to support planning systems first evolved in the mid 1960's. Computer systems were entirely confined to larger organisations who could afford to buy or rent the necessary hardware. These systems often had their origins in research establishments and involved the use of simple databases describing crop and site conditions for yield forecasting applications. The systems were very inflexible as they relied on batch processing methods, often using hardware at a computer bureau. The systems were not designed to support highly interactive needs of the 'what if' type. All of the 'what if' applications were met by non computerised systems assuming they were met at all. These systems gradually developed and were often brought in house on to centrally installed 'mainframe' hardware. The development of the systems was largely a reflection of the cost, quality and power of the available hardware. Additional, stand alone applications (eg. financial control systems) were developed to maximise the use of spare hardware capacity.

During the 1970's and early 1980's, the cost of hardware fell or rather the data storage and processing capacity per unit cost increased. The ultimate expression of this was perhaps seen in the abundance of microcomputers installed in organisations by the early 1980's. They provided users with direct access to computing power, utilising package software or low level bespoke software. These new computer based systems also introduced opportunities for more extensive data analysis and presentation. The result of this was considerable pressure from users to develop systems to meet needs presently met by paper based systems.

The systems that were developed often only met a limited range of needs both within the same level and between different levels in the same organisation. Many organisations introduced microcomputer systems to support administrative functions rather than pure forest planning techniques (Joyce and Breen, 1986: Robak 1986). Many forest operations planning systems continued to be paper based. The primary benefit of these types of development was to enable many users to gain hands on experience. At the very least this could be regarded as an investment in education by helping to remove much of the mystique surrounding computer systems which had their origins in scientific establishments. Credibility too was gained in that users who had always seen a particular series of problems were provided with a relatively quickly available solution. The development of these systems, assuming some form of centralised control or at least awareness allowed data processing professionals to become more aware of organisational needs and gain a wider understanding of the users point of view.

In the organisational context, multiple capture and storage of the same data was commonplace. This created difficulties in ensuring data consistency. Often staff responsible for 'data creation' found they were entering the same data into different computer systems in the organisation. In addition, where standardised solutions were developed for installation at all management levels, individual units found that their needs were often not adequately met and consequently, locally derived systems (both computer and paper based) continued to be operated.

The development of microcomputer systems in the 1970's and 1980's reflected the systems designers main problem, an inability by users to clearly express their needs. In a climate of increasing user awareness, systems were often enhanced or upgraded to meet new or extended needs. These needs were often only identified as a result of the immediately preceding experience of development and a realisation of the constraints and new opportunities once live running commenced. Often the end product, if it ever reached a final state, was totally different from the need defined before the system was born. Authors such as Koten (1986) have reported similar systems development histories elsewhere so it is likely that the United Kingdom experience is fairly representative on a world wide basis. This style of development is also not particularly unique to the forestry industry. It probably mirrors the history of systems development in most organisations. However by the late 1980's there was a growing awareness that there was a different and perhaps better way of approaching systems development.

## A STRATEGIC APPROACH TO SYSTEMS DESIGN

Perhaps one of the most controversial areas that computer systems open up is the validity of individual applications. In some cases this can include the justification for holding data at given locations and in others the justification for holding the data at all. The ability to hold and process large amounts of data means that temptations can exist to make use of it for it's own sake.

It is reasonable to assume that data should be collected to meet a specific need or range of needs. These needs should properly reflect the activities performed by the organisation. In small organisations the range of activities may be limited and consequently the data required to plan and control adtivities may also be relatively limited. In large organisations, a wide range of activities may be followed and consequently more data may be required. Frequently the same data is required by several users, albeit viewed in a different way and with different understanding. In these latter situations the same data is often collected more than once and where computer systems are used the cause is often incompatibility between individual systems in terms of freedom of data exchange. For example most forestry organisations hold databases containing descriptions of crop, site, area and yield parameters. In some organisations more than one physical copy of the same database is held and inevitably these get out of step if proper controls for updating and amendment are not in place. The end result of this can be that two individuals asking the same question against individual databases will get different answers. In other words the data has lost credibility and value.

One of the penalties of this approach is that it becomes very easy for a system to be viewed as an end in its own right. This largely reflects the basis on which the system was originally developed, that is, to meet a relatively narrow range of needs.

In an organisational context, there should only be one system. All management levels will make use of different components of the system reflecting differing scales of business activity, for example areas of planting, volumes of timber harvested and so forth. It follows therefore that the proper place to begin the design of a corporate system is by looking at the business needs of the organisation as a whole.

This will involve a review of the objectives of the organisation supported by the organisations top (strategic) management level. The review will re-define how the objectives are to be implemented and state how they are to be planned and controlled. The review will then work out to the tactical and operational levels of management. The analysis will include a statement of each current physical component and will reduce it to a logical component. This will in effect produce a high level model of the organisation together with detailed lower level models of each component. The model, if correctly produced will also clearly define the links between each individual component. During the course of this analysis, the activities of the organisation, at all levels, should be questioned for validity and tested against the model. If necessary the model should be revised to reflect changes in activities and exclude any that are no longer identified as valid.

The process described above is a classical systems analysis approach. The major difference is that instead of being application driven it is business driven in the corporate sense. It is important to realise that the process is not intended to limit localised needs but to ensure that any individual needs correctly relate to overall needs. In medium and large sized forestry organisations there will probably be relatively few 'stand alone' applications that are uniquely performed at individual operational management units. The differences that do occur will reflect variations in the scale, timing and relative importance of individual activities. Since the organisational structure (should)exist to pursue overall aims and objectives it follows that unless a policy of centralisation has been adopted for a particular function then any operational activities that appear to be unique should be viewed as separate organisations.

In forestry there are very few organisations that can boast a truly all embracing planning and control system capable of serving the needs of all individual units in the organisation. For example database (Stand register), yield forecasting and more recently mapping components are often linked together. Similarly, cost and performance histories and accounting and administrative components are linked together. The links between the medium and long term forward planning components and the actual achievement components are relatively few. Where they do occur, they tend to be confined to a narrow range of forest operations, for example harvesting.

## STRATEGIC SYSTEMS AND THE BENEFITS FOR OPERATIONAL PLANNING AND CONTROL

In the United Kingdom, plantation forestry is the most significant form of silviculture. This has involved the creation of new forests over a period of some 70 years. Many of these forest areas are now maturing and decisions have to be taken about preparing for the second rotation - felling and replanting. A typical operational case involves assessing the economic implications for felling stands of timber, the yield and marketing implications, the harvesting resource requirements and alternative methods including roading requirements, as well as the environmental implications in terms of landscaping, conservation and so forth. In addition the consequential effects for replanting including site cultivation, plant supply and subsequent maintenance need to be considered. These are usually expressed in cost, revenue, quantity (area, volume) and geographical (mapping) terms. These processes also need to take account of tactical and strategic factors such as market commitments, employment policies and so forth.

The processes are iterative and the degree and extent of definition will increase as the timing of the felling operation approaches. Full use should be made of data relating to the past performance of similar operations and where available, work study derived data. This is one of the fundamental tasks of operational managers. However other managers at different levels will also need to make use of this data for quite different tasks. At other operational levels such as nurseries, where they have been concentrated to achieve economies of scale and expertiese, managers will need notice of species requirements and total numbers. At the tactical level for example, staff concerned with machinery purchase will need to be aware of future programmes. Equally staff concerned with marketing will need to be aware of the production planning implications to ensure a regular and even supply of timber into the market.

The development of such an all embracing system is not easy, nor can it necessarily be achieved quickly. Many organisations will already have several of the individual components in place and in regular use. Few will have achieved total integration. This is largely because the individual components will have been developed on an ad hoc basis.

Consequently all organisations, large and small, should adopt proper business activity driven standards for systems development. This will help to ensure that future links between individual components are possible. Individual 'stand alone systems' should be viewed as relatively short term solutions to an immediate need. These short term solutions will ultimately be absorbed into the corporate system, assuming they meet real needs. This style and pattern of development is not unique to forestry organisations. Indeed most commercial organisations have developed their information systems in this way. The processes, pressures and penalties have been comprehensively described by Martin (1981). The properly designed system will ensure that managers at all levels enter their data once only and each component will subsequently ensure that is is presented to other appropriate levels in the organisation in the correct way at the right time. As operational managers are the major data creators in organisations, this will relieve them of the need to service a seemingly endless series of 'requests' for more data or more of the same data.

## NEW COMPONENTS FOR THE FUTURE

Within this framework of a strategic approach to systems design there are a number of new tools and techniques that are emerging and will further enhance the effectiveness of forest operations planning processes.

### Geographic Information Systems

Geographic Information Systems (GIS) are now becoming more commonplace in many organisations. Systems such as that described by Carbonnier (1989) enable existing information to be related to known geographic features such as national grid reference co-ordinates, contour (altitude) data, physical features (rivers, roads and so forth). These will enable forest managers to readily model and view the physical effects of operations such as felling and replanting. The major constraint in achieving this is usually the large investment required to digitise the physical and crop features to enable computer storage. However recent advances remote sensing interpretation are increasing opportunities and reducing data collection and translation costs.

Developments in computer graphics have enabled 3 dimensional representations to be produced. In the United Kingdom this will offer significant opportunities for the planning of for example, landscape sensitive operations. In addition many alternative approaches can be tested and evaluated without making frequent field visits or using relatively inflexible and conventional photographic techniques. Linking the GIS component to other components within the strategic system means that yield, resource, cost and revenue implications can readily be defined, tested and manipulated within the context of the overall designed plan.

### Simulation and Animation

The development of simulation techniques which are graphically as opposed to mathematically presented will enable the planning of more complex, dynamic operations to be improved. The ultimate development of such systems is in the form of animation (Corcoran 1989, Corcoran and Metcalf 1989). In very large forestry organisations whose activities include harvesting, transport and processing this will help to improve machinery deployment and utilisation and also give greater control over stocks at each stage of the complete process.

## Portable Computers

Computer based systems will move closer to the point of data creation that is, out into the forest itself. Hand held or portable hardware, capable of withstanding the rigours of the forest environment will be introduced. In addition automatic links between these data capture devices and office based systems will appear, for example by using radio modem technology. The data capture devices will also be able to receive the results of analysis by the office based system so that the manager is rapidly aware of the implications of changes as they happen.

Critics of such an approach will argue that forest managers will become removed from reality and manage operations entirely through the computer system. However, provided that the organisation manages the computer system and ensures that it is recognised only as a tool, the real benefit will be the release of managers to properly consider and evaluate the real implications of their plans and also to anticipate where plans may need to be modified to ensure success. The result will be that many operational managers become far more proactive rather than reactive. The forest manager of the 21st century faced with the breakdown of a key machine for example will already have anticipated this and have a solution prepared and ready to implement.

In addition, managers will become far more involved with and feel responsible for the quality of the data they introduce to the system. Although it will hopefully never be necessary to record precision for precisions sake, managers will be able to direct their efforts to areas where more accurate or more up to date data is required. Perhaps most importantly, managers will spend their time evaluating the implications and implementing effective solutions. In other words the results will be increased productivity and lower costs as a result of better informed decision making.

## CONCLUSIONS

The development of systems in the late 1970's and 1980's was rightly user driven. In many cases, users had little or no previous exposure to computers and often were initially sceptical of the benefits. In addition the process of development often showed up the inability of managers to define their information needs in objective and logical ways. The development of these systems, often using prototyping techniques, was a valuable educational investment. As a result individual managers improved their ability to state their needs and systems designers were better able to place them within the context of the strategic activities of the organisation.

This experience and knowledge now offers unique opportunities to develop systems capable of meeting the full range of information needs of organisations. The development of future systems will largely be unconstrained by technology and be business rather than application driven. Systems development will only really be constrained by factors of cost and benefit to the organisation.

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# STANDARDS FOR EVALUATING FOREST MACHINE PERFORMANCE

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## SUMMARY

Variability in the methods used to collect and report information from operational studies of forest machines has produced a knowledge base that is inconsistent and fragmented. Using incompatible formats to organize information makes it difficult or impossible to build a comprehensive knowledge base. This decreases the usefulness of the knowledge and results in unnecessary duplication of effort. This paper discusses the problems associated with nonstandard data collection and reporting procedures. Current efforts addressing the problem in North America are also discussed. The problem is international in scale and will require an aggressive, concerted effort on the part of the forest engineering community if standard procedures are to be developed and used.

Keywords: Standards, forest engineering, machinery, performance

## INTRODUCTION

Evaluating forest operations produces new knowledge about the capabilities, costs, and impacts of equipment and methods used in the forest. Publishing this information adds to the available knowledge in the forest engineering discipline. This knowledge provides a basis for making decisions pertaining to forest operations, which ultimately affects the efficiency and cost of these operations.

The format used to collect and report information will determine its contribution to the knowledge base. Forest engineering information is normally collected using widely accepted methods of work measurement. However, specific details of data collection and reporting vary widely, resulting in a knowledge base that is inconsistent and fragmented. Information that is inconsistent with the knowledge base will provide little added knowledge. Recent efforts to build computerized data bases have made the depth of the problem apparent (Rickards et al. 1988).

The only way to avoid this problem is to develop and use standard methods of collecting and reporting information from forest operations. The forest engineering research and evaluation community currently has no internationally accepted standards. The need has long been recognized (Jarck 1965, Berard et al. 1968, Spanjer 1968, Warkotsch 1981, Sutherland 1984, and Stuart 1985), but coordinated action on the problem has not been taken.

Standardization must be accomplished on an international scale. Markets for wood, wood products, and forest equipment are global in nature. It is very important that countries involved in cooperation and trade have common methods of evaluating performance to reduce the barriers to effective communication. The development of internationally accepted standards for terminology, techniques, units, etc. will provide for smoother exchange of goods, services, and information throughout the world.

The objective of this paper is to promote the development and use of standards for collecting and reporting information in forest engineering. Methods used to report machine performance are presented and difficulties associated with using nonstandard data formats are discussed. Current efforts in the United States aimed at alleviating the situation are highlighted.

## ATTRIBUTES OF PERFORMANCE INFORMATION

The performance of a machine is measured as the quantity of useful work it completes in a given period of time, along with the costs and damages associated with the operation. The amount of work completed by forest equipment is normally measured as the volume or weight of wood transported or processed in a given time period. Depending on the particular forest operation being evaluated, it can also be measured as the area of residue treated, the area of ground prepared, the number of seedlings planted, the area of ground covered with herbicide, pesticide, or fertilizer, or the length of road built, per unit of time. Also included in the performance measure are the costs of the operation, the effectiveness of the operation in completing the particular objective, the impacts of the system on the residual stand and site, and the background conditions present during the evaluation.

Machine performance depends on many site, stand, and operating factors. Users of performance information are often interested in estimating and comparing machine productivity, costs, effectiveness, and damages for very specific operating conditions. Therefore, the amount of detail available in reported information will often determine its value to the user.

The level of detail associated with machine performance information is determined by several attributes of the information. Although these qualities are interdependent, each will be discussed separately in the analysis. The discussion will focus on collecting and reporting machine productivity and cost information.

## Duration

Duration pertains to the length of time over which data have been collected. Long-term data have been collected over a significant portion of the machine life and therefore reflect the average of many fluctuations and changes in conditions. Short-term data, on the other hand, have been collected for only a small portion of the machine life, making it likely that the information has been biased by random events that did or did not occur during observation.

The duration represented in performance information follows a continuum from a practical minimum of several hours to a maximum equal to the life of the machine. Long-term data typically come from 1 to 5 years of recordkeeping on a particular machine. This information is normally obtained from daily or weekly records of volume produced, hours worked, oil and fuel consumed, major breakdowns and delays, and purchases of parts and supplies. Most short-term data come from 2 to 3 weeks of detailed observation of a particular machine, but can extend for 6 months to a year in some cases.

From the standpoint of accuracy, long-term data are generally preferred to short-term; however, the difficulty and cost of collecting detailed long-term data are often prohibitive. Therefore, the use of a combination of long- and short-term information is often most practical. Short-term evaluation is used to effectively describe the repetitious elements of the machine cycle where detail is very important. Long-term evaluation is used to describe less predictable or fluctuating events and costs where overall averages are important. When used together, these approaches present an accurate picture of machine performance at reasonable cost.

## Time Element Classification

Forest operations consist of a series of work elements associated with accomplishing a particular task. Table 1 presents a typical classification of time elements for the work cycle of a cable skidder. Each element requires a certain amount of time to complete; some are repetitive (hook, winch, etc.), some are periodic (scheduled maintenance, breaks, etc.), and others occur at random (delays, breakdowns, etc.). The amount of time required to perform each element will vary from cycle to cycle as a function of many different factors. If these individual elements are measured enough times, reliable average times can be calculated. These can be summed and combined with average cycle volumes to determine productivity.

The reason for dividing the machine cycle into logical work elements is to provide more detailed information about the work. Individual elements can be scrutinized in light of the specific factors influencing them, and operational improvements can be tested. Better cause/effect relationships can be developed for individual elements than for the entire cycle, resulting in better correlations. Individual work elements can be used to describe new operations or operating situations in which no information is presently available. Finally, elements can always be added to produce totals, but gross data cannot be divided into elements.

Table 1. Time element classification for a cable skidder (fictional data)

| | Time per cycle (minutes) | Portion of total (percent) |
|---|---|---|
| **Productive elements** | | |
| Travel empty | 2.32 | 11.4 |
| Position | 0.18 | 0.9 |
| Hook | 4.56 | 22.3 |
| Winch | 0.62 | 3.0 |
| Travel partially loaded | 1.93 | 9.5 |
| Travel loaded | 3.04 | 14.9 |
| Unhook | 0.87 | 4.3 |
| Deck | 0.36 | 1.8 |
| Total productive time | 13.88 | 68.1 |
| **Mechanical delay elements** | | |
| Refuel | 0.11 | 0.6 |
| Maintenance | 0.39 | 1.9 |
| Wait for repair | 0.08 | 0.4 |
| Repair | 1.84 | 9.0 |
| Transport for repair | 0.04 | 0.2 |
| Equipment warm-up | 0.03 | 0.1 |
| Total mechanical delay time | 2.49 | 12.2 |
| **Nonmechanical delay elements** | | |
| Breaks | 2.73 | 13.4 |
| Discussions | 0.21 | 1.0 |
| Blade skid trail | 0.54 | 2.7 |
| Drop hanger | 0.15 | 0.7 |
| Tow haul truck | 0.05 | 0.2 |
| Stuck | 0.32 | 1.6 |
| Injury | 0.02 | 0.1 |
| Total nonmechanical delay time | 4.02 | 19.7 |
| Total time | 20.39 | 100.0 |

Observed performance:

Average load size = 6.53 $m^3$

Machine utilization = 68.1%

Mechanical availability = 87.8%

Productivity = 19.2 $m^3$/scheduled hour(SH) or 28.2 $m^3$/productive hour(PH)

Productivity (assuming a long-term utilization rate of 64%) = 18.1 $m^3$/SH.

The degree to which cycles are divided into elements can range from none to a maximum determined by the number of logical elements in the cycle. This logical maximum may not be achievable in practice due to the speed at which the element occurs relative to the measuring time. Other factors affecting the degree of subdivision into elements are the objectives of the particular study and the resources (manpower and dollars) available to conduct the measurements.

## Time Reference

Productivity and cost information can be specified over several different time bases. When specified on the basis of total time, all time elements are included in the value. This includes nonworking as well as working time and is specified as productivity or cost per day, week, month, year, etc. This basis is typical of gross data. The problem with this type of information is that the reader often does not know how much working time these figures represent. Production rates that appear to be quite different might be due only to the amount of time worked.

When productivity and cost information is specified on a scheduled time basis, nonworking time is ignored. The performance measure is based on total working time, which includes both productive and delay time. It is usually expressed on the basis of one scheduled hour and is the most realistic and informational approach.

When a performance measure is specified on a productive time basis, only productive time is considered; delay time is ignored. This basis is not realistic because many operations considered as delays are nonetheless necessary for successful completion of the operation. This neglected component of time may differ significantly between equipment or methods and, therefore, should be considered in machine evaluations.

## Variable Association

The performance of forest equipment depends heavily on a host of external factors, such as tree characteristics, terrain, skidding distance, operator, markets, etc. Users of machine performance information often must estimate productivity and cost for specific conditions to prepare bids, schedule resources, and compare alternatives. Therefore, information that contains predictive relationships is often of most value to users.

Predictive relationships that account for one or more important factors can be developed in several ways. The first and most common method is to develop an empirical relationship, which is a predictive model based on observed responses. Empirical models are developed by measuring the dependent variable (such as productivity) for as many possible combinations of the independent variables as is feasible or necessary. Regression equations and correlation measures are developed from this information using statistical analysis techniques. These techniques are based on inference and, in some cases, may result in erroneous relationships.

A less common method used to develop predictive relationships is mathematical modeling. In this case, a model of the relationship that exists between variables is developed from physical and mathematical laws. These can be very accurate, but the complex interactions typical of forest operations make them difficult to develop with accuracy.

A third method of developing predictive relationships consists of computer simulation. The actual operation is mimicked with computer code, resulting in performance predictions. This method is very useful for predicting the response of exceedingly complex processes, but it is difficult and costly to develop. Over the long term, however, computer simulation can be a cost-effective method of evaluating new technology that would be very expensive to build and field test.

Finally, predictive relationships can be developed by combining any of the three previous methods. Combining the empirical and mathematical methods is a very common and useful approach. Using this method, much of the observed variation can be accounted for with physical relationships and a portion of the remaining variation can be accounted for empirically.

The number of variable associations made in predictive relationships can range from none to as many as are important and can be measured. Predictive relationships can be developed for any measure of performance, from gross production figures down to single time elements. Common variables modeled include load size, elemental time, cycle time, machine productivity, machine cost, system productivity, and system cost. Models should not be assumed valid outside the ranges of the variables used to develop the relationship.

### Statistical Significance

The statistical significance of performance measurements depends on the number of observations made in relation to the size and inherent variability of the population being sampled. This differs extensively among reported information in forest harvesting. It will range from incalculable for most of the gross figures reported to quite high for very detailed analyses. This can be deceiving, however, because although gross figures are normally presented as a single figure, they often represent the accumulation of years of experience and observation by the individual making the estimate. Although the statistical significance of these figures is incalculable, they can be very reliable over the long term.

## COMMON PERFORMANCE REPORTING FORMATS

The attributes discussed previously each contribute to the level of detail represented by reported performance information. Because each attribute follows a continuum, the number of possible combinations of these attributes in performance figures is unlimited. There are, however, a few common combinations reported in forest harvesting journals. These can be categorized as gross figures, case studies, and factor analyses.

### Gross Figures

Gross figures have little obvious detail. They usually amount to a single number expressing the productivity of a machine or system for some time period (e.g., 350 $m^3$ per week) or the cost for some unit of volume (e.g., \$14 per $m^3$). This type of reporting is very common in harvesting trade journals where the estimates are based on the experience of the operator rather than extensive analysis. Gross figures can be very reliable over the long term because they typically represent the average of all the conditions normally encountered by the operation. They are often used to complement detailed short-term performance information.

### Case Studies

Case studies are short-term evaluations designed to measure machine performance for the conditions present at the time of the study. Observing the machine or system under a range of conditions is often attempted, but is not usually considered a major goal of the analysis. The information is typically very detailed, but the limited range of measurements often does not allow for sophisticated statistical analysis. Table 1 presents performance information typical of case studies. The information is accurate only over the short term and for the observed conditions. Combining these numbers with long-term estimates of availability and utilization makes them more useful. Associating several case studies performed under a variety of operating conditions for a machine or system improves the value of the information to the user. This is where a standard reporting format becomes very important.

### Factor Analyses

Factor analyses are studies designed to evaluate the effect of one or more variables on performance. Changes in the independent variables are controlled to whatever extent possible, and the performance response is measured. A model of the relationship is developed from the empirical information, with some of the observed variation possibly being explained mathematically. An advantage of this approach is that it allows for the prediction of performance. However, it is often difficult and expensive to conduct, is short term in nature, and will often show a low level of statistical significance due to the large amount of unexplained variation typical in forest operations.

## PROBLEMS WITH NONSTANDARD FORMATS

The format used to present performance information differs considerably with the evaluator, the study objective, and the format used to collect data. The method of presentation often determines the extent to which the information can be used. Problems with nonstandard data formats are discussed in the following sections.

## Incomplete Information

Machine performance is often reported without enough background data to thoroughly describe the conditions under which the information can be expected to apply. The reasons for omission of this vital information are many and varied, but can often be traced to an oversight in the data collection phase. Therefore, it is very important to carefully plan for data collection to ensure that all pertinent information is recorded. It is usually too late to go back and fill in gaps in the data after the measurements have been taken.

There are two major problems associated with using incomplete information. First, the user does not know enough about the conditions under which the data were collected, and therefore doesn't know what limitations apply to the use of the information. The user, then, is taking a chance applying this information to any and all conditions. This undermines the credibility of the information, even in situations where it should be considered reliable.

The second major problem with using incomplete information is that the evaluator cannot account for variability between reported figures based on the background conditions. Differences in reported information are often due to subtle differences in the underlying conditions of the operation. However, the reasons for these differences cannot be evaluated if the background conditions are not reported. Again, this reduces the reliability and usefulness of the information.

There are several ways that information could be considered incomplete. The first is neglecting to record and report all pertinent conditions influencing the operation. The number of possibly significant variables is overwhelming; therefore, the decision of whether or not to measure each variable must be made with the cost of collection and importance to performance in mind. A standard data collection format can help ensure that all possibilities are considered during this preliminary screening.

Another way performance information can be incomplete is when it is presented with no indication of duration (long-term vs short-term), time basis (based on scheduled or productive time), or statistical significance. These attributes are critical to properly applying the information and should be reported.

Major assumptions used to calculate performance measures are often neglected during reporting. This is especially true for cost calculations. This limits the usefulness of the information in terms of being able to apply it to the particular conditions experienced by the user. This also limits the ability of the user to extract more basic information from the reported figures.

Performance models are often presented without reporting the average values observed during the evaluation. Although not critical, this information can be very useful to an evaluator who has no other source of reliable input data. This information can also be important in applying the model accurately to unique conditions.

Another problem with reported information has to do with cost. Cost is often reported without the underlying productivity relationships. This reduces the value and limits the useful life of the information. Aside from the added value of the productivity information, presenting productivity relationships along with cost allows users to update cost calculations, effectively extending the useful life of the information.

### Inconsistent Formats

Completeness of presentation does not ensure the usefulness of performance information. The data must also be consistent with accepted formats in the forest engineering discipline. This is especially true for the division of time into elements. Once time information is collected in a particular format, it is normally impossible to convert to a different time element classification. It is also difficult to compare performance figures that have been developed using different time and cost assumptions. Conversions can be made if the assumptions are stated, but this is often too time-consuming for most purposes. Conversions can also be inconsistent if accepted conversion factors have not been defined.

### Inadequate Data Analysis

Performance information is sometimes presented only in basic forms that are difficult to use. Although presentation of the basic data is important, subsequent analysis can greatly enhance the convenience and ultimate usefulness of the information to users. Further analysis of reported data will not be done by most users. Standard data analysis procedures would help ensure that sufficient analysis of the information is performed.

## CONCLUSIONS AND RECOMMENDATIONS

The difficulties associated with nonstandard data formats point to a need for more consistent methods of reporting evaluations in forest engineering. The most effective means of promoting consistency is to develop standards for collecting and reporting performance information. Based on the previous analysis, it is recommended that performance evaluation standards specify the following:

1) The use of SI units in all communications.
2) Standard terminology for forest operations and equipment.
3) Standard terminology for forest machinery management.
4) Standard methods to document the background conditions of the evaluation.
5) Standard methods to document additional factors important to the particular evaluation in question.
6) A standard format to present the background conditions.
7) Standard time element classifications.

8) Standard costing procedures.
9) The use of standard costing assumptions when actual data are lacking.
10) Standard methods for wood measurement.
11) A standard format to present the results of the evaluation, to include the following:
    a) All assumptions used in the analysis, along with the source of and reasons for making the assumption.
    b) The duration represented by the information (long- vs short-term).
    c) The time basis of the information (SH or PH rather than hour).
    d) The cost of production as a combination of the productivity and a time-based cost.
    e) The statistical significance and the method used to find it.

## Current Efforts

In the United States, standards development in forest engineering is being pursued by two major organizations, the Society of Automotive Engineers (SAE) and the American Society of Agricultural Engineers (ASAE). The main thrust of the SAE is to develop specification definitions, component nomenclature, and engineering design standards for forest machines. The following is a list of standards projects of the SAE:

| | |
|---|---|
| J1014 | Classification and Nomenclature Towing Winch for Skidders and Crawler Tractors |
| J1084 | Operator Protective Structure Performance Criteria for Certain Forestry Equipment |
| J1109 | Component Nomenclature - Articulated Log Skidder, Rubber-Tired |
| J1110 | Specification Definitions - Articulated, Rubber-Tired Log Skidder |
| J1111 | Component Nomenclature - Skidder - Grapple |
| J1112 | Specification Definition - Skidder - Grapple |
| J1158 | Specification Definitions - Winches for Crawler Tractors and Skidders |
| J1209 | Identification Terminology of Mobile Forestry Machines |
| J1212 | Fire Prevention on Forestry Equipment |
| J1254 | Component Nomenclature - Feller Buncher |
| J1255 | Specification Definitions - Feller Buncher |
| J1272 | Felling Head Terminology and Nomenclature |
| J1316 | Swing to Load Hydraulic Log Loader Lift Comparison Method |
| J1353 | Component Nomenclature - Clam Bunk Skidders |
| J1354 | Component Nomenclature - Forwarders |
| J1511 | Steering for Off-Road Rubber Tired Machines |
| J1822 | Guidelines for Winch Operation and Installation on Log Skidders |
| J1823 | Specification Definitions - Forwarders |
| J1824 | Specification Definitions - Clam Bunk Skidders |
| J2055 | Identification Terminology and Component Nomenclature - Knuckle Boom Log Loader |

These are very important and well-written standards from an engineering design point of view. However, aside from the general definitions provided by these standards, they offer little guidance for evaluating forest machine performance.

The main thrust of the ASAE, on the other hand, is to develop a series of standards designed specifically to provide guidance for evaluating and reporting forest machine performance. The planned framework for these standards is as follows:

1) Terminology for Forest Operations and Equipment - divided into two major sections, the first defining accepted terminology for forest operations and the second defining accepted terminology for forest equipment (with a standard symbol for each basic machine type).

2) Terminology for Forest Machinery Management - divided into four major sections, the first defining accepted terms associated with work measurement, the second defining specific elements of machine time, the third defining specific elements of machine cost, and the fourth defining various measures of machine performance.

3) Performance Evaluation of Forest Machines - divided into two major sections, the first specifying accepted methods of calculating various measures of machine performance and the second specifying accepted methods of evaluating time and cost for forest machines.

4) Assumptions for Performance Evaluation of Forest Machines - divided into two major sections, the first specifying accepted time element classifications for forest machines and the second specifying accepted assumptions for costing forest machines.

5) Guide for Planning and Reporting Evaluations of Forest Operations - divided into three major sections, the first specifying factors to consider when planning evaluations of forest equipment, the second specifying a systematic method to document key factors during the evaluation, and the third specifying a systematic method to report the results of the evaluation.

6) Forest Machinery Data - intended to be a standard reference for performance information of forest machines.

7) Wood Measurement - divided into three major sections, the first specifying accepted methods of measuring some physical characteristics of wood, the second specifying an accepted classification system for wood products, and the third specifying accepted conversion relationships for wood.

At present, a draft of "Terminology for Forest Operations And Equipment" is out for review. The second draft should be ready for review in the summer of 1990. Work on the remaining planned standards will follow in logical sequence.

Both organizations recognize the importance of having standards accepted internationally. As the only worldwide forestry research organization, IUFRO would be the ideal organization to oversee and coordinate the forest engineering standards efforts taking place around the world. Developing and using internationally accepted standards should greatly enhance research, evaluation, the development of new technology, and the exchange and use of information in forest engineering.

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# STANDARDIZATION RULES OF INFORMATION SYSTEMS AND THEIR APPLICATION IN INTEGRATED FOREST OPERATIONS PLANNING AND CONTROL

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## SUMMARY

One of the vital conditions for integrated forest operational planning is the standardization of elements of forest operation systems. System standardization is a continuous task due to constant change of the factors in forestry systems, and to the change of their relation to the environment.

The paper deals with the rules that need to be followed in standardization of system elements, and the impact of individual rules on regulation and functioning of the system. It then analyses the extent to which these rules have been applied in the standardized systems in forestry. Differences in standards result in difficult communication within forest operation systems as well as in communication between forest systems and environment. Difficulties the level of forest working site, operations systems in forest enterprises, on national, and international level. The paper offers some possible ways to eliminate these difficulties, and connect the systems by applying standardization rules in planning and control of forest operations.

# MODELLING FORESTRY SYSTEMS: USERS' PERSPECTIVES OF RESEARCHERS' SOLUTIONS

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## SUMMARY

Appropriateness of the general design of models used in forest planning is queried from users' points of view. Critical examination is made particularly of the strategic relevance of historical forest management objectives, of the consequential elements that make up planning models, of the successful integration of individual parts of whole planning and management systems, of the timeliness and quality of assumptions frequently found in models and of the dangers of misusing and misdirecting modelling capabilities. Suggestions are made on how researchers and users of research modelling tools can assist each other in improving the relevance and quality of forestry system modelling.

Keywords: modelling, research, management, control

## INTRODUCTION

The planning and management of forestry systems today is dominated by (some observers would say unduly obsessed with) models and modelling. There has indeed been a proliferation of modelling tools developed by researchers in the last twenty years, but the more and more that are produced the less and less any one of them appears to be utilised by those for whom it was custom built. Indeed, there is an apparently growing resistance among managers and decision-makers against relying on sophisticated planning models as decision support tools; e.g. with respect to multiple-use management, Kirkland (1989) in an address to the 13th Commonwealth Forestry Conference did

> *"not believe that the quest for more and more data to plug into increasingly esoteric models which purport to define objectively the financial, economic, social and environmental trade-offs is the answer"*.

Personal observation in various countries during visits over the last few years suggests that, at the level of management of single forests, such decision-support tools are often neglected. Rules of thumb, which managers relied on so heavily in former years, are now being easily and frequently applied through data base and spreadsheet systems, possibly after some manipulation of basic data at the stand level. The forest level decision-support tools are neglected or, at best, under-utilised and so the sophistication of stand-level analysis is thus severely compromised. If this is generally true, then researchers need to examine the reasons why such resistance is growing and how the tools they have been developing for decision-makers and managers should be redesigned to provide a better service.

This paper, therefore, outlines the broad framework of forest modelling systems, summarises the characteristics of the main kinds of solution procedures, reviews the adequacies of each kind for the purposes to which they are actually put, queries the relevance today of the directions for which these procedures were intended and suggests how improvements in the overall efforts could be achieved. Disraeli's remark more than a century ago, namely

*"What we anticipate seldom occurs; what we least expect generally happens"*.

is a timeless warning for researchers in this context. The premises on which traditional forest research priorities were based may well no longer apply, and so, before striving to improve more and more the capabilities of such tools, we should critically consider first where we could and should be heading.

## OVERVIEW OF FORESTRY SYSTEMS MODELLING

Forest management is often regarded as both an art and a science. Its origins as a science evolved in central Europe, primarily because of a shortage of wood: the rigid approaches to regulating timber yields, epitomised by the optimal rotation model of Faustmann (1849) and the normal forest standard so central to early European forest management resulted mainly from a fear of inadequate supplies. The underlying concepts and simplistic regulation formulae were exported to all parts of the world: some were adapted not at all and others only to a small extent, so that even today, the traditional views are still tightly held. Forest management systems and the associated modelling requirements in most countries all tend to have the structural form shown in Figure 1.

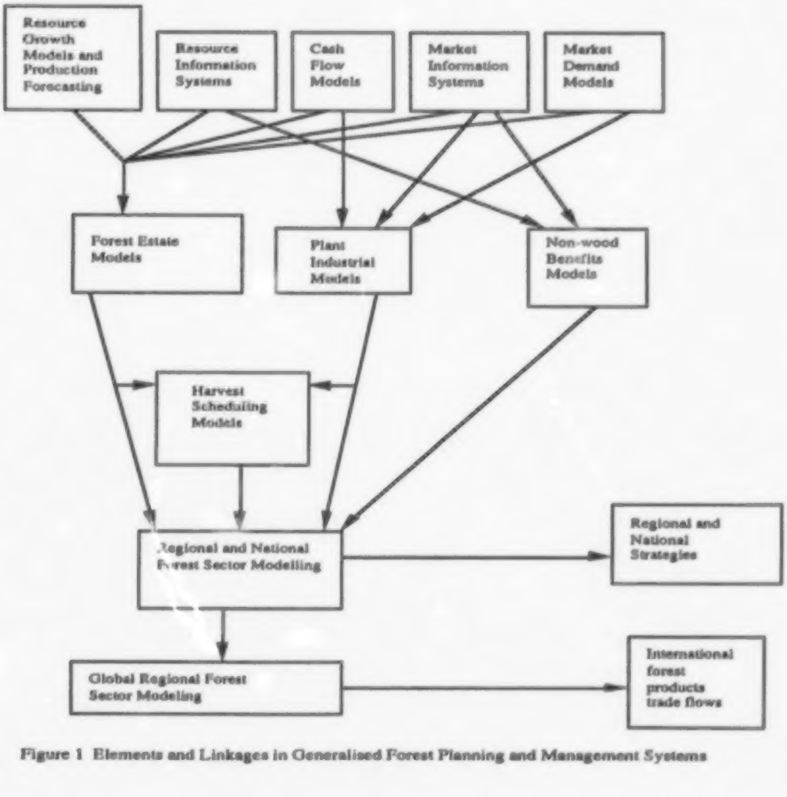
Resource Growth Models and Production Forecasting
Resource Information Systems
Cash Flow Models
Market Information Systems
Market Demand Models
Forest Estate Models
Plant Industrial Models
Non-wood Benefits Models
Harvest Scheduling Models
Regional and National Forest Sector Modelling
Regional and National Strategies
Global Regional Forest Sector Modeling
International forest products trade flows

Figure 1 Elements and Linkages in Generalised Forest Planning and Management Systems

In most cases, forest managers have some form of historical information about the forest resources they oversee and means of forecasting their future production; the two are generally integrated to some extent. The resource information is aggregated by management units of some sort; e.g. by inventory strata, or stands or even sub-stands, but these unit aggregations may vary from time to time and place to place, and so introduce a lack of consistency which complicates planning and management. Often the resource information is not directly supported with financial data; consequently the linkages between the physical and fiscal resource information systems have to be created each time they need to be linked. Both are, however, likely today to be data-base management systems, though not necessarily compatible one with the other. The growth models and yield forecasting procedures vary greatly from one organisation to another: in some instances they may be no more than normal or variable-density yield tables that may or may not have stood the test of time; in other instances, they may be sophisticated growth models, usually at the stand level and with or without disaggregation by dbhob classes, while in others they may be simply an average mai of volume per unit area. Generally growth and yield are modelled through simulators.

Difficulties start to appear if the units of aggregation in inventory systems differ from those relating to other resource information or to the financial records or to the growth models or to the estate models. Further complications arise because important resource indices change as crops mature. Provision should be made for such contingencies as shown in Whyte(1987), but is not in much evidence generally in the published literature.

Forests consist of many stands each with their own distinctive characteristics of growth, yield, accessibility, management practices and so on. Strategies which are optimal at the stand level rarely sum to the best option for the forest as a whole (see e.g. de Kluyver *et al.*, 1980a). Simulators and mathematical programming models are the two most usual tools used for the process of modelling whole forest estates. Both tools require a resource description over time in terms of area, yielding capability, accessibility, harvestability, location, ownership and so on: in simulation, the user specifies areas to be harvested, regenerated, planted or otherwise treated and an output of various yields for specified scenarios can be created; in LP and other optimising procedures, the model is used to identify management strategies which maximise utility for a forest owner subject to various constraints. Both techniques tend to become too large and cumbersome for easy use and interpretation, as modellers strive for better and better realism. Model I and Model II formulations that have been recognised by Johnson and Scheurman, 1977 for LP models, moreover, do not cater adequately for the flexibility in mixing silviculture options and management regimes, which plantation forestry managers need to examine.

Proponents of one or other solution procedure often promote mathematical programming and simulation as self-contained alternatives. The two approaches should, however, most definitely not be regarded in such a way: rather, they are complementary. What researchers should be providing is an integrated modelling structure whereby the broad strategic directions for wood supply can be identified through mathematical programming procedures and then their consequences further analysed in greater detail, but for smaller components, through simulation. That sort of capability is being encouraged in New Zealand through the development in tandem of FOLPI (Garcia, 1984), a forest-level optimisation model, and IFS (Garcia, 1981), a forest-level interactive simulator: the two use the same input files and produce identical output reports and can therefore be used in truly complementary fashion. FOLPI users need to specify an objective function and set of constraints in addition to the volumetric and value yield tables contained in IFS. Multi-period solutions obtained through Model II formulations to optimise harvests, replanting and crop type transfers can then be explored in more detail for similar or shorter planning horizons. That coordinated capability already exists, but is not practised to any great extent by managers at different levels within the same organisation.

Plant industrial models may be for a single or, more and more commonly, for several integrated processing plants (e.g. combinations of plymill, sawmill, reconstituted wood product mills, pulp and paper mills). Most single plant models use simulation to assist with decision-making, mainly because techniques such as LP fail to address satisfactorily the random nature of log inputs, machine downtimes and other such variable aspects, and because optimisation techniques do not represent supply buffers and process bottlenecks very readily (Sampson, 1979). Examples of single plant models include GEMS (Edwards *et al.*, 1987), a general energy and material simulator for the pulp and paper industry. The capital-intensive nature of pulp, paper and reconstituted wood industries has relied heavily on automation and process-control technology, thus creating an environment that is amenable to real-time process simulation. More recently, there has been renewed interest in trying to use large-scale LP modelling for monitoring and controlling pulping and pulp-blending (e.g. Hara *et al.*, 1987).

Vertical integration of several production processes in a multi-product forest industry can allow economics of scale and eliminate several transportation and processing cost elements that have to be represented in the structure of single plant production. Integrated wood processing is characterised by having several possible sources of raw materials and intermediate products, with each individual process varying in its raw material requirements and in its production or consumption of different amounts of intermediate products. The simplest form of integrated industry modelling involves just straightforward aggregating of single mill models that are individually solved. This is akin to using stand-level aggregations for whole forest estate modelling and is subject to the same drawback, namely that the optimal policy for the whole plant is not necessarily the sum of optimal policies for each of its constituent elements.

This disadvantage appears to have been reasonably well understood and so most integrated industry models in use today are log-allocation models based generally on LP. They address the problem of allocating a limited supply of one or more classes of log to the various manufacturing processes so as to maximise returns. Linkages between corporate industrial modelling and single processes do not feature prominently enough in the literature, in just the same way that linkages of whole forest models to stand level components are rarely in evidence.

There is, moreover, a tendency to have a lack of proper balance between what forests can supply and what processing should be done with either a fixed supply of log types or unlimited supplies of each log type. Some recent harvest scheduling models are, however, paying more and more attention to linking the two (e.g. Barros and Weintraub, 1982), but other consideration such as providing various environmental, amenity, wildlife, recreational and other such safeguards need to be more fully addressed. In fact, many management and harvest scheduling decisions are influenced more by political and other such factors that are not part of any formal quantitative modelling than by the facets and relationships embedded in such models. That may be a major reason why there is a growing resistance to reliance on models, as will be further discussed later.

Regional, national and global planning for the forest sector is very much concerned with such model externalities. Whyte and Baird (1983), for example, listed a wide range of important elements which could be considered desirable in striving for adequate representation. Those so identified were :

- determining possible supply capabilities over time
- forecasting market demands for various kinds of forest products
- regenerating, tending and harvesting crops and importing products so that supplies and demands are matched
- transporting raw materials, intermediate and final products
- selecting, locating, building and operating processing plants
- financing the associated capital investments
- rationalising and regulating the use of energy, other raw materials and people

(especially skilled labour )
- resolving and catering for the consequential infra-structural needs for vehicles, equipment, roads, port-facilities and shipping capabilities
- imposing realistic levels of environmental and social constraints
- providing linkage to other sectors and other countries.

Nilsson (1983) also provided a similar list for models suitable for forest sector analysis. He proposed that they should:

- be usable for several time periods
- be regionalised
- allow alternative forest management options
- deal with each industry as a separate unit
- allow analysis of several goals simultaneously
- allow alternative usage of forest biomass
- consider the financial aspects of the sector.

These lists are by no means comprehensive; e.g. recreation and amenity forestry do not appear to be of immediate consideration, but obviously no one single model nor one research group on its own is capable of representing such a wide range of functions effectively. It is for this reason, perhaps, that forest sector analysts the world over have been slow to plan and manage at this level. While some integrated mill models and forest estate models have been used in this context (e.g. Weintraub *et al.*, 1986), none has the capability to represent the complex interactions that exist throughout the sector, and so they are all likely to produce unsatisfactory results. Planning at the forest and lower levels consequently proceeds in little better than a vacuum.

Several methodologies are employed to generate appropriate forest sector strategies: dynamic simulation, mathematical programming and econometric spatial equilibrium models are the three most prominent approaches, but systems dynamics and optimal control theory have also been tried. There is often a mix of techniques employed, rather than just one on its own. Dynamic simulation models are exemplified in Lonnstedt (1986), Sedjo (1986) and Grainger (1987); mathematical programming in Kallio *et al.*. (1985), Whyte and Baird (1983), Kirjasnieni (1986) and Johnson and Whyte (1990); spatial equilibrium models by Adams and Haynes (1980), Dykstra and Kallio (1986) and Brooks (1987); systems dynamics by Randers (1976); optimal control theory by Dyer and McReynolds (1970), while a mix of techniques is employed by Gilless and Buongiorno (1987) with respect to the North American pulp and paper industry. The problems in all of these, but in some more than others, is the ability to strike the right balance between wood processing, forest products, marketing and wood supply, and also the difficulties in disaggregating trade flows in sufficient detail within a region.

What could be of much more significant concern, however, is that even with a hierarchical modelling structure that can allow disaggregation, as explained in Whyte (1987) and briefly outlined later in this paper, not enough emphasis is placed by researchers on feedback, flow-on and control mechanisms for utilising models at any level, nor are the variable inputs to regional and national sector models the ones that affect political decisions and, hence, what is made to happen. Leslie (1989), for example, discusses the irrelevance of forest managers' preoccupation worldwide for timber self-sufficiency, when the real problem is whether or not substitution will occur because of timber's uncompetitiveness on a local scene, and that future planning in Australia, which he was addressing specifically, should be concerned with preparing to cope with factors such as the greenhouse effect, the resource-preservation movement, tourism in forests and privatisation of state forest resources. The current crop of forest and forest sector models pay scant heed to these latter issues, yet they are the factors which will largely dictate forest managers' decision-making. Is it any wonder, then, that some managers are either turning away from using models or else abusing their true capabilities?

Examples of abuse of stand and forest level models by New Zealand managers is given in Whyte (1988) and (1989a). In summary, he claimed that default values and historical knowledge, which may be unrepresentative of the current and future resources, are too firmly embedded in models purporting to plan the future. While the models are capable of being subject to sensitivity analysis, the numbers of sub-models and variable inputs per sub-model produce so many permutations, that the process becomes an exercise in futility and one, consequently, that is likely to be ignored altogether.

## DESIRABLE MODELLING FEATURES

Two examples of modelling systems are briefly outlined below, one at the forest level and the other at the sector level, in an attempt to illustrate some basic modelling principles which researchers might find useful to examine and debate. The actual form and structure of the models and what they purport to represent and analyse are really incidental to the arguments being developed here, but some brief reference to these aspects has to be made in order to highlight the underlying principles being advocated.

A decision-support system for managing tropical pine plantations systems was outlined by Whyte (1978) then, after various additions and refinements, again in Whyte (1987) and (1989b). In the last of these contributions, descriptions of various sub-systems that make up the managerial process are given: the main ones emphasised are marketing, wood delivery, yield forecasting, inventory, establishment and tending, and research support. Two of these, yield reconciliation and harvesting, are referred to here to illustrate the coordinated planning functions and control features represented in the whole decision-support system.

A yield reconciliation sub-system is needed by forest managers, because planned production forecasts are rarely, if ever, actually realised. Irrespective of the size of the discrepancy, it is highly desirable that managers should be aware of them, where they are occurring, what is causing them and how to reduce them in future. They can occur at several points in the management system; for example, because of unsatisfactory logging technique, incomplete or inappropriate log recovery, incorrect bucking, inexact inventory, biased functions such as equations for predicting stem volume or stem taper or height or growth, and illegal leakages. The system referred to integrates the inventory, yield-forecasting, planning and control processes and caters specifically for ongoing calibration of inbuilt functions in particular. For instance, during crop development inventories conducted under a sampling with partial replacement strategy, remeasurement allows the consistency of growth equations to be checked, while pre-harvesting inventories involve collection of data in such ways that the reliability of existing equations to predict height, volume and taper can be tested at times that are most relevant, and then current cull factors can be revised realistically. These calibrations, together with estimates of the amount of logging waste obtained through line intersect cruising and comprehensive scaling of wood actually delivered, are then used for reconciliation of yield. Temporary local adjustments are able to be made to one equation or another from time to time, and a data-base gradually accumulated that could provide the means for making periodic major revisions, if found necessary.

The reaction of managers to this feedback and calibration process is generally one of querying if all such special effort is needed. Today's plantation forest managers often identify another dimension to this problem of reliably forecasting future production and use it as an excuse for cost-cutting. They claim that models based on historical data cannot adequately portray future crops grown from genetically improved tree seed and estimated to make substantial gains ( e.g. 25 to 30 per cent yield improvement in New Zealand radiata pine, according to Carson, 1987). But such gains will likely be gradual rather than instantaneous, and so the calibration process described in the previous paragraph has an even more important role to play in assisting managers. Remove any one of the elements and reconciliation will be totally compromised. It is true, however, that historically based equations may be misleading if they are not of a satisfactorily functional form, but that is not an issue being examined here and is indeed important enough to warrant separate treatment beyond the scope of this paper. Suffice it to say, that a calibration capability is becoming even more vital as the intensity of management is forced relentlessly to increase, but how many researchers build it routinely into their models or, if they do, how can they ensure that managers actually conduct adequate calibrations and apply the results of them properly?

The harvest planning sub-system in that same Fiji situation is still confined to the medium and short-terms; long term harvest planning is currently embedded within wood supply modelling as crop type aggregations for forest estate modelling, which performs no detailed scheduling, of course, by individual stands or other aggregated units of similar size. Medium term planning, explained in de Kluyver *et al.* (1980b), is done through an annually revised linear programming model for the first 5 to 7 years of the long-term wood supply schedule. It aims to provide a maximum net discounted revenue from the harvests subject to constraints on minimum contractual supplies, feasible deliveries to utilisation centres, use of logging machinery, manpower and transport, and on administrative convenience. The main aim of the planning tool is to measure the financial loss through implementing a schedule a manager prefers to adopt rather than the theoretical optimum, and to determine the infra-structural consequences such as annual requirements for equipment, roading and transport. The planning unit at this level is classified in terms of age and topography for a given species within a forest felling series. The short term planning is, as detailed in Eng *et al.* (1986), done at the level of individual logging settings, which can easily be disaggregated from, or aggregated to , the units for medium-term planning. The tool consists of 2-stage DP/LP in which the DP simply identifies non-dominated bucking strategies for up to 100 stem size and quality classes and the LP chooses the best mix of bucking strategies given the market demands for various log sizes and qualities over a whole year. While there is good coordination between the 5 to 7 year medium-term plans and the single year short-term plans, there is neither the same capability nor sensitivity to coordinate shorter-term operational fluctuations within any one year, nor to bridge the gulf between medium and long-term horizons.

But even if there were full integration over all horizons, there is the further complication that such planning refers to a single organisation, whereas marketing is often concerned with wood flow from more than one forest-growing organisation at a time. Regional and higher-level analysis, therefore, is often conducted quite separately and usually without much coordination among organisations. An attempt has been made to provide an adequate framework for this express purpose. Its structure was outlined by Whyte and Baird (1982) and consists of a hierarchy of mathematical programming models at the top of which is a national model that can be disaggregated first into regions, then into forests and finally into groups of stands within forests. Running parallel to this series of disaggregations is the capability to choose the desired emphasis with which to represent growing, harvesting, transporting and processing of the raw material. The whole system is able to be decomposed naturally because of the block-diagonal structure of the models. The various levels can be solved individually, then re-solved iteratively in order to produce a stable coherent set of solutions for all levels jointly. It should be acknowledged that the system has not been much used by the forest industry, except as described in Baird and Whyte (1987), a major reason being that the modelling required access to a specific main-frame computer and associated software not readily available outside the university.

This and a perceived lack of user-friendliness is a commonly found source of irritation between researchers and managers. Researchers need to be more alert and sensitive to managers' working habits. The latter appear to be relying more and more heavily for for their routine management decision-making and auditing on spreadsheet and data-base systems that are available on microcomputers. Researchers should pay particular heed to this trend and could take best advantage of it if they design decision-support tools around packages and microcomputers that managers actually use. Even data inputs and report outputs from large LP models can now be handled in this way as reviewed in Sharda (1988), since the time of publication of which several more spreadsheet-based optimisation tools have been developed.

## SUMMARY OF CONCLUSIONS

Discussion here has indicated that there is an ever-increasing flow of decision-support tools being produced by researchers, but that managers are showing reluctance to use them or else choose to use them inappropriately. Major concern is expressed for the apparent lack of balance between planning and control mechanisms in systems modelling and in coordinating decision-making and review processes at levels of management ranging from administering single operations through to regional, national or global strategic plans. In examining the strengths and weaknesses of two examples used to illustrate possibly how researchers might consider building more desirable features into decision-support tools, emphasis is given to the advisability of providing a modelling capability which takes cognisance of whole systems, which can be broken down into manageable parts, which provides interactive and iterative means of obtaining coherent solutions that are as little subject to precluding assumptions as possible, which has formal auditing and calibrating routines built into it and which takes advantage of computer software and hardware regularly used by management.

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# HARVESTING SYSTEMS FOR *Pinus sp* IN BRAZILIAN PLANTED FORESTS

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FDC: 31: 66: 174.7 *Pinus* spp.: (81)

## SUMMARY

Brazil has a great potential for reforestation because of its vast territory. Up to 1988 approximately 6,9 million ha. had been planted, 5,5 million of which are already intended for various segments of the forestry industry. The forest harvesting systems for *Pinus sp* in South Brazil present great variation regarding machinery, teaming, revenue and costs. The partial activity which costs the most is transportation.

Keywords: reforestation, harvesting systems, costs, yield

## INTRODUCTION

Brazil, given its vast territory, has had its agricultural frontiers continually extended, while its forestry industry develops with higher technology. Native forests have been replaced by cattle farms, by agricultural crops, and by planted forests of *Pinus sp*.

Inventories done in South Brazil, where some of the great forests of *Pinus elliotti* and *Pinus taeda* are found, show many differences regarding harvest systems, yield and costs. These differences are related to the type of forest, either native or planted, to its stage of growth, to the location, and to the species. Other variables are the size of the forestry company, its location and objectives, and the training of its employees.

My objective here is to analyze the economic implications of various harvesting systems as opposed to the present reality of the Brazilian forestry industry.

## THE FORESTRY INDUSTRY IN BRAZIL

Wood consumption in Brazil totals 250.000.000m3 per year, which corresponds to 0,4% of the present potential in the Amazonian forest. The internal consumption increases in 4% yearly, almost three times more than the average world demand. This means that the Brazilian internal consumption of wood will nearly double by the end of the century.

Another important point is the gradual drainage of tropical hardwood resources in Africa and Asia, which may increase the demand for Amazonian wood.

The 1988 internal consumption of wood products in Brazil, as well as the country's reforested area per product and the respective revenue, can be verified in Table 1.

Table 1: Wood product consumption, reforested area, and revenue of the forestry industry in Brazil for 1988 (Siqueira 1989)

| Industry | Total reforested area available (1000ha) | Wood consumption (1000m3) | | | Revenue Billion US$ |
|---|---|---|---|---|---|
| | | native | planted | total | |
| Paper/ pulp | 1.177,98 | 8.000 | 26.100 | 34.100 | 3,219 |
| Lumber | 1.200,00 | 13.440 | 8.960 | 22.400 | 2,725 |
| Coal | 1.916,61 | 70.000 | 16.560 | 86.560 | 3,418 |
| Composition boarding | 1.200,00 | 490 | 4.410 | 4.900 | 1,100 |
| Fuel/ rural energy | - | 127.200 | 10.980 | 138.180 | ? |
| Totals | 5.494,59 | 219.130 | 67.010 | 286.140 | >10,462 |

It is important to emphasize the fact that the sector of lumber also includes plywoods, and that 40% of the total consumption originates in the Amazon, 20% in other native forests, and 40% in planted areas.

On the basis of the revenue and wood consumption numbers, it is clear that the sector of composition board industry has the best performance, followed by the sectors of lumber, paper and pulp, and of coal.

It is estimated that 16,5 million ha. should be planted to the end of this century in order to reduce the utilization of native forests in Brazil. This is to meet the demands of energy and manufacture, as well as the wood product export goals. With the presently available planted areas, a production of 75.000.000 m3 per year can be estimated. But there is a deficit of 190.000.000 m3 which is complemented by native forests. It is also estimated that Brazil has reforested 6.9 million ha., 1.4 million of which still have no planned use (Siqueira 1989; Galvão 1984.)

The sectors which destroy the most native forests are those of fuel for rural energy, and of coal. It is actually difficult to determine the real consumption of fuel, and of the revenue which it generates. Up to the present, there are no significant reforested areas which could be used for fuel and rural energy.

Compared to other countries with forestry activity, Brazil appears to allow advantages when its potential for reforestation is considered:

a) availability of lands for massive reforestation;
b) a short rotation (12-20 years) for Pinus and Eucalyptus, which take 25-30 years in the United States, and 80-100 years in Scandinavia and Canada to reach comparable volume;
c) a significant growth of the world market for short fiber;
d) low costs of wood and labor.

The main comparative disadvantages are:

a) the high cost of capital (inflation, etc...);
b) the low level of labor training;
c) the internal market restrictions for forestry machinery;
d) the high cost of imported machinery.

## THE FOREST HARVESTING SYSTEMS FOR Pinus sp IN BRAZIL

The forest exploration systems in Brazil are very diverse for native forests such as the Amazon and others, as is harvesting for homogeneous forests, mainly of Pinus and eucalyptus.

The great majority of the Pinus reforestation areas are in South Brazil and have been planted since 1965, with fiscal incentives which are not available anymore.

With the maturation of these forests, harvesting began, according to known techniques suitable for native forests. As time went by, however, these methods were considered inapropriate, and adaptations to the conditions of the planted forests were made.

Each company tried to match the harvesting system to its reality the best way, either according to labor adequacy, to the availability of equipments in the market, to its infra-structure and investment capacity, or to the final product revenue, and other factors, such as forest succession. These differences still occur, and what can be observed nowadays are several harvesting systems, each varying according to yield and costs.

A research project was conducted in order to evaluate the usual systems, with data collection in companies of three types according to wood consumption:

- major (demand greater than 20.000 m3/month)
- average (demand between 3.000 to 20.000 m3/month)
- small (demanding less than 3.000 m3/month).

Three systems of exploration were observed for the great companies, as illustrated in table 2. Exploration costs totalled US$ 5,03/m3 for system I, US$5,16/m3 for system II and US$4,66/m3 for system III. We may also verify that equipment, teaming and cost percentages varied from system to system.

Table 2: Yield and costs for three exploration systems of Pinus in major companies (>20.000m3/month)

| Activity | System | Operation | Production means | Team size ** | Yield m3/h/ team | Cost US$/m3 | % of expl. cost |
|---|---|---|---|---|---|---|---|
| Wood preparation | I | felling<br>branching<br>cross-cutting<br>piling | chain-saw<br>axe | 1+7 | 4,06 | 1,29 | 25,64 |
| | II | felling<br>branching<br>cross-cutting* | chain-saw<br>axe | 1+7 | 4,57 | 1,13 | 21,90 |
| | III | felling<br>branching<br>cross cutting* | chain-saw | 4+0 | 6,60 | 0,47 | 10,09 |
| Skidding | I | harvesting to storage area | 4x2 truck | 1+2 | 4,09 | 1,07 | 21,28 |
| | II | harvesting to storage area | tractor + locked bar and chain | 1+1 | 4,88 | 1,18 | 22,87 |
| | III | harvesting to storage area | farm tractor+ grapple | 1+0 | 6,60 | 1,23 | 26,39 |
| Loading | I | loading for transp. | by hand | 0+4 | 12,0 | 0,19 | 3,78 |
| | II | loading for transp. | small loader | 1+1 | 20,0 | 0,37 | 7,17 |
| | III | loading for transp. | medium loader | 1+0 | 42,0 | 0,11 | 2,36 |
| Transportation | I | transp. (40 km) | 6x2 truck | 1+0 | 2,75 | 2,48 | 49,30 |
| | II | transp. (40 km) | 6x2 truck | 1+1 | 2,75 | 2,48 | 48,06 |
| | III | transp. (30 km) | 4x2 truck | 1+0 | 3,20 | 2,85 | 61,16 |

* cross-cutting in storage place

** the first number refers to the machine operator
the second number refers to the helpers

Table 3: Yield and costs for three forest harvesting systems of Pinus sp in average size companies (3.000 tp 20.000 m3/month)

| Activity | System | Operation | Production means | Team size ** | Yield m3/h/ team | Cost US$/m3 | % of expl. cost |
|---|---|---|---|---|---|---|---|
| Wood preparation | I | felling branchig cross-cutting | chain-saw axe | 1+5 | 3,00 | 1,91 | 30,61 |
| | II | felling branching cross-cutting* | chain-saw | 1+0 | 2,30 | 1,50 | 17,22 |
| | III | felling branching cross-cutting* | chain-saw | 1+0 | 2,50 | 1,45 | 24,25 |
| Skidding | I | harvesting to road | tow with return cable | 1+2 | 5,00 | 1,51 | 24,20 |
| | II | harvesting to road | horse | 1+0 | 1,15 | 1,40 | 16,07 |
| | III | harvesting to road | farm tractor+ grapple skidder | 1+0 | 6,80 | 1,18 | 19,73 |
| Loading | I | loading for transp. | medium loader | 1+0 | 45,00 | 0,10 | 1,60 |
| | II | loading for transp. | medium loader | 1+0 | 38,70 | 0,11 | 1,26 |
| | III | loading for transp. | medium loader | 1+0 | 44,00 | 0,10 | 1,67 |
| Transportation | I | transp. (50 km) | 6x4 truck | 1+0 | 7,20 | 2,72 | 43,59 |
| | II | transp. (67 km) | 6x4 truck + cart | 1+0 | 3,60 | 5,70 | 65,45 |
| | III | transp. (40 km) | 6x4 truck | 1+0 | 3,40 | 3,25 | 54,35 |

* cross-cutting in storage place after harvesting

** the first number refers to the machine-operator and the second numbers refers to the helpers

Table 3 presents revenue, costs, and teaming for three forestry exploration systems of Pinus sp. in average size companies.

The costs per cubic meter in this case totalled US$ 6,24 for system I, US$ 8,71 for system II, and US$ 5,98 for system III. In this case we also observe great variation amongst systems, revenue, and costs, with the greatest cost and discrepancy having been caused by transportation in system II, which amounted to 65,45% of total costs.

Given the greater number of small companies and their harvesting difficulties, I decided to investigate five harvesting systems used by them. The results regarding revenue, costs, and others, can be verified in Table 4.

As in the previous cases, variation is clear. Harvesting costs per cubic meter totalled US$ 9,08 for system I, US$ 5,80 for system II, US$ 4,84 for system III, US$ 4,63 for system IV, and US$ 3,65 for system V. In this case transportation was the most expensive part of the system.

We may also verify that physical labor is heavily used, with little and/or poor utilization of machinery for forest harvesting tasks. Loading is usually done by hand, causing great physical strain.

It is in the sectors of Table 4 that systems used for native forest exploration in the past still appear.

Another important point regards labor. While the major companies have their own labor for most activities (except transportation), most small companies hire contractors, normally doing forest harvesting with the help of family members who have learned through practice, but lack technical background and have no knowledge about equipment and security.

## NEW FOREST HARVESTING DEVELOPMENTS FOR Pinus sp IN SOUTH BRAZIL

Given the percentual rise of social security benefits which the employer has to deposit, and since the beginning of sindicalization of forestry workers, many companies have, nowadays, been adopting mecanization from the second thining on. Such companies include the major and average-size ones, which rely on machinery even when costs are slightly higher if compared with physical labor.

Felling has also been changed with the introduction of feller-bunchers with shears or saw, according to the production objectives.

In flat or slightly-hilly topographies, companies prefer to harvest without entering the plots by truck, to avoid soil compacting. Forwarders without traction (4 x 4 farming tractors with hydraulic loader and a cart), and forwarders with traction, that is, hydraulic motors that pull the cart wheels directly, are being developed for these cases.

Table 4: Yield and costs of five forest harvesting systems of Pinus sp in small companies (>3.000 m3/month)

| Activity | System | Operation | Production means | Team size | Yield m3/h/team | Cost US$/m3 | % of expl. cost |
|---|---|---|---|---|---|---|---|
| Wood preparation | I | felling<br>branching<br>cross-cutting<br>pre-hauling | chain-saw<br>horse | 2+1 | 1,30 | 1,87 | 20,59 |
| | II | felling<br>branching<br>cross-cutting<br>piling | chain-saw<br>axe<br>by hand | 1+4 | 1,75 | 1,66 | 28,62 |
| | III | felling<br>branching<br>cross-cutting<br>piling | chain-saw<br>axe<br>by hand | 1+5 | 1,75 | 1,33 | 34,64 |
| | IV | felling<br>branching<br>cross-cutting | chain-saw<br>axe | 1+5 | 3,40 | 1,56 | 33,69 |
| | V | felling<br>branching<br>cross-cutting<br>piling | chain-saw<br>axe<br>by hand | 1+3 | 2,30 | 2,09 | 57,26 |
| Harvest | I | harvesting to storage | tractor +bar+chain | 1+1 | 2,50 | 3,47 | 38,22 |
| | II | harvesting to storage | 4x2 truck | 1+2 | 6,00 | 1,11 | 19,14 |
| | III | harvesting to storage | 4x2 truck | 1+2 | 4,40 | 0,89 | 23,18 |
| | IV | harvesting to storage | animal (bulls) | 1+1 | 1,75 | 0,47 | 10,15 |
| | V | harvesting to storage | animal (bulls) | 1+0 | 1,93 | 0,40 | 10,96 |
| Loading | I | loading for transp. | small loader | 1+1 | 10,00 | 0,23 | 2,53 |
| | II | | by hand | 0+3 | 8,00 | incl. in transp. | |
| | III | | by hand | 0+4 | 11,00 | incl. in transp. | |
| | IV | | by hand | 0+4 | 11,00 | incl. in transp. | |
| | V | | by hand | 0+4 | 11,00 | incl. in transp. | |
| Transportation | I | transp. 18km | 4x2 truck | 1+0 | 3,20 | 3,51 | 38,66 |
| | II | 130km | 6x2 truck | 1+0 | 2,10 | 3,03 | 52,24 |
| | III | 145km | 6x2 truck | 1+0 | 2,00 | 2,62 | 42,18 |
| | IV | 27km | 6x2 truck | 1+0 | 1,87 | 2,60 | 56,16 |
| | V | 12km | 4x2 truck | 1+0 | 4,20 | 1,16 | 31,78 |

Transportation from 50km on is generally semi-heavy (truck plus cart), or heavy (truck plus two carts, with total gross weight up to 70 ton.).

An additional aspect of importance in harvesting and reforestation nowadays is that company technicians are aware of the necessity of infra-structure planning, especially in regard to the felling direction, hauling, storage areas, difficulties while working the plot, and the features of the road system.

## CONCLUSIONS

- The harvesting of _Pinus sp_ in South Brazil is dynamic, with various systems.

- Transportation is the partial activity which costs the most.

- Lower exploration costs were attained in systems which rely more heavily upon physical labor, and upon contractors, in the case of small companies.

- Mecanization in forestry exploration is a matter of time, and its introduction in partial activities such as felling and hauling is inevitable.

- Workers in major and average-size companies receive some training, while small companies provide practically no training.

- The usual form nowadays is that of sawlogs; fewer companies prefer the tree-length system.

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# COMPARING TWO TERRAIN TRANSPORT MEANS IN A TROPICAL HIGH FOREST

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## SUMMARY

Two terrain transport means, a crawler tractor and a wheeled skidder used in a tropical high forest were time studied in order to provide information on the production rate.

In both transport means, skidding production was greatly influenced by the skidding distance. For the wheeled skidder, production rate was also influenced by the load size, log length and soil coditions. Soil moisture was found to reduce skidder's speed, load turn and consequently the production rate by about 63 percent.

To increase skidder's productivity, it is recommended to buck the stems into short logs, prepare skid roads in advance and organize work in such a way that the crawler works on difficult wet terrains and the skidder on the dry and simple terrains.

Keywords: Tropical high forest, transport means, work elements, cycle time, production rate.

## INTRODUCTION

Natural forests occupy about 443,700 km$^2$ or about 47 percent of the total land area in Tanzania. About 2 percent of the natural forests are under tropical high forests and mangrove forests while the rest (98 percent) is classified as miombo woodland forests (Dykstra 1983).

Tropical high forests occur primarily on mountain areas where the amount of rainfall is high and the soils are still very fertile. Because of the high quality timber species found in this type of forest, most of the forests have been heavily exploited. At present the production and exploitation potential is declining. Pitsawing and crawler tractors have been and still are the main methods and means of harvesting timber from this type of forest.

Wheeled skidders were first introduced in the natural forests in Tanzania in the late 1970s. Since then, its number has increased and are becoming popular due to their high manoeuvrabilty and high travel speeds as compared to crawler tractors. Today the choice of the skidding equipment depends on the stand density, volume per log, undergrowth, ground conditions and other terrain characteristics. On steep terrains (over 30 percent), crawler tractors are preferred while skidders are more confined on terrains less than 30 percent. Where the stand density is low and the skidding distances are over 200 metres, the use of wheeled skidders is encouraged.

A number of time studies and production rates in logging operations in softwood plantations and miombo woodland forests have been undertaken in Tanzania (Dallu 1977, Abeli and Dykstra 1981, Ole Meiludie and Dykstra 1982, Migunga and Dykstra 1983). So far little has been reported on timber harvesting in tropical high forests (Abeli et.al. 1988). This paper compares two ground skidding means; the crawler tractor and a wheeled skidder skidding sawlogs in the tropical high forest. Through time study analysis, the paper compares the production rates of the two machines under varying terrains, soil and ground conditions, load sizes and the skidding distances.

## MATERIALS AND METHODS

This paper is based on studies conducted at one tropical high forest, Kwamkoro Forest Reserve, on the slopes of the Usambara mountains near Tanga (Issara 1986, Mwayungu 1986). The forest lies at 38.5°E longitude and 4.9°S latitude. During the study period, day temperatures fluctuated between 22°C in the morning and 26°C in the afternoons while relative humidity averaged 78 and 71 percent respectively. The terrain slopes varied between 10 and 25 percent while the stock density was about 190 $m^3$/ha. Tree diametres averaged between 90 and 100 cm while merchantable volume per tree was about 1.80 $m^3$. Both studies were undertaken in 1986 at the beginning of the long rains.

Data on production rate in terrain transport was collected from detailed time study using continuous timing. Two tractors, a 1979 D7 model Caterpillar crawler tractor, 150kW engine capacity, and a 1984 model 518 wheeled skidder, 90kW engine capacity, were used to skid logs from the stump to a road side landing. The independent variables measured, recorded and expected to influence the production rate were ; ground slope, distance, load size, log length, ground and soil conditions. Ground conditions were assessed on a four class variable based on difficulties due to the obstacles and density of undergrowth and debris. Soil condition was classified into: dry, moist, wet and very wet, by (i) observing the state of the traversed tracks and (ii) pressing soil samples between the thumb and forefinger. These classes were described as follows:

Class 1. dry: dust when working on it; provides hard surface.

Class 2. moist: not dusty when working on it; gives cold feeling when in contact with the skin.

Class 3. wet: plastic, permanently deformed when traversed; can be rolled into small threads when pressed.

Class 4. very wet: muddy on tractor trails; water drops when pressed

In order to facilitate data collection, analysis and interpretation, each skidding turn formed one cycle time. Each cycle time was segregated into the following work elements;

Return: travelling empty from the landing to the stump site.

Skidding: travelling loaded from the stump site to the landing.

Loading: chocking and winching logs until a full load was obtained.

Unloading: un-chocking and piling logs at the landing.

For each skidding turn, effective work element times, necessary and unnecessary delay times were recorded. Effective and total work element times were statistically analysed to see if there were any relationships with the variuos independent variables. Time study data were also used to establish production rates for the two terrain transport means.

Log volumes were determined by use of a Smalian formula while the skidding distances were measured in metres by using a measuring tape. Ground slopes were measured by use of a Suunto clinometre. The data collection period covered 12 and 16 days for the crawler tractor and wheeled skidder respectively while the respective total number of trips made were 92 and 104.

## RESULTS AND DISCUSSION

Table 1 shows work element times, the percentage of each work element time to the total effective time, delay times and total cycle time.

Table 1: Summary statistics for work element times.

| Type of machine | Statistic | Return | Loading | Skidding | Unloading | Total Effect. | Delay time |  | Total cycle |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  | Nec. | Unnec |  |
| Crawler tractor | mean | 5.04 | 3.99 | 5.92 | 0.73 | 15.68 | 5.24 | 5.51 | 26.43 |
|  | min. | 0.37 | 3.00 | 0.22 | 0.11 | 5.01 | 0.00 | 0.00 | 5.03 |
|  | max. | 16.7 | 8.50 | 22.8 | 5.16 | 35.33 | 87.31 | 43.53 | 107.83 |
|  | %. | 32 | 25 | 38 | 5 | 100 | - | - | - |
| Wheeled skidder | mean | 4.68 | 3.77 | 8.78 | 0.68 | 17.92 | 4.99 | 6.88 | 29.79 |
|  | min. | 1.38 | 0.70 | 3.52 | 0.18 | 8.02 | 0.00 | 0.00 | 9.26 |
|  | max. | 13.1 | 23.7 | 30.9 | 6.48 | 41.44 | 50.99 | 165.7 | 184.9 |
|  | %. | 26 | 21 | 49 | 4 | 100 | - | - | - |

In both skidding means, the percentage of the effective time was only 60 percent of the total cycle time. Preparation of the skid roads, identification and pre-chocking of logs could greatly reduce delay times. Skidding or travelling loaded was the most time consuming work element in both cases. This means therefore, if skidding production is to be improved, more emphasis has to be put on this work element. Both loading and unloading times for wheeled skidders were less than crawler tractor despite bigger load sizes due to high flexibility and manouverability of the skidder both at the stump sites and at the landings. The influence of various independent variables on work element times, total effective time, total cycle time and production rate are discussed below:

## Return

For both means, time to drive empty from the landing to the stump site depended on the distance. Soil condition and ground slope did not seem to have any influence on the return empty time. Regression equations (1) and (2) can be used in predicting return times for the crawler tractor and the wheeled skidder respectively:

$$TRc = 0.86 + 0.0284D \qquad (1)$$

$$R^2 = 89.3\%$$

$$TRs = -0.37 + 0.01D \qquad (2)$$

$$R^2 = 51.8\%$$

Where $TRc$ = return time for the crawler tractor, min
$TRs$ = return time for the wheeled skidder, min
$D$ = travel distace, m
$R^2$ = coefficient of determination

## Skidding

The travelling loaded time was strongly correlated with the skidding distance. Literatures show that skidding distane is the most important variable affecting skidding production; the longer the distance, the more skidding time and consequently the less skidding production. According to Conway (1986), the optimal skidding distance for crawler tractors is about 200 m while that of wheeled skidders is about 400 m. In these studies, the average skidding distances for the crawler and skidder machines were respectively 127 m (10 - 450 m) and 477 m (150 - 720 m) showing that they were within the acceptable range. The significant effect of distance on influencing the travel times has been reported by other researchers like Bjaanes (1970), Fiske and Fridley (1975), Ole Meiludie and Dykstra (1982) and Olsen and Gibbons (1983).

In the case of crawler tractor, the load size which averaged about $3.3m^3$ ($1.4 - 15.9m^3$) had a small influence on the skidding time as equation (3) shows:

$$STc = 0.52 + (0.0338 + 0.00263V)D \qquad (3)$$
$$R^2 = 81.1\%$$

Where STc = skidding time for the crawler tractor, min
V = load size skidded per turn, $m^3$

For the wheeled skidder, besides skidding distance, the skidding time was very much influenced by the number of winchings. The number of winchings varied from 0 to 12 and was influenced by the load size, log length and soil conditions as equation (4) shows:

$$NBWINs = (0.066V - 0.15)LL \times SOIL \qquad (4)$$
$$R^2 = 48.2\%$$

Where NBWINs = number of winchings by the skidder
LL = log length, m
SOIL = delays due to soil moisture, i.e., class 1: 1.8, class 2 and 3: 6.4, class 4: 17.7.

Longer logs were more difficult to manoeuvre hence more winchings required. The number of winchings also increased with increase in soil moisture. Total skidding time when using wheeled skidder could thus be estimated by equation (5) as follows:

$$STs = 3.64 + 0.0065D + 1.24NBWIN \qquad (5)$$
$$R^2 = 43.3\%$$

Where STs = skidding time for the wheeled skidder, min

Average travel speeds when loaded were less than when empty for both skidding machines. Table 2 shows crawler speed both when loaded and empty.

Table 2: Travel speeds for the wheeled skidder

| Variable | Average | minimum | maximum |
|---|---|---|---|
| Return (empty) speed (m/s) | 0.46 | 0.23 | 1.00 |
| Skidding(loaded) speed (m/s) | 0.38 | 0.12 | 0.92 |

As equation (6) shows, the skidder's travel speed was influenced by the load size, soil condition and the skidding distance:

$$TSs = 0.975 - (0.123 + 0.0235SOIL)V + 0.0014D \qquad (6)$$

$$R^2 = 50.2\%$$

Where TSs = travel speed for the wheeled skidder, m/s

The effect of moisture content on reducing the bearing capacity of the soil and traction of wheeled vehicles and hence skidding productivity has been reported by Legault and Powell (1975) and Scholander (1973). Table 3 shows that there is an evident of a decrease in the average and maximum travel speed with increase in soil moisture.

Table 3: Wheeled skidder travel speeds under different soil conditions

| Soil condition | | Return speed (m/s) | | | Skidding speed (m/s) | | |
|---|---|---|---|---|---|---|---|
| Moisture | Class | mean | min. | max. | mean | min. | max. |
| Dry | 1 | 1.92 | 0.73 | 3.37 | 1.22 | 0.42 | 2.22 |
| Moist | 2 | 1.80 | 1.24 | 2.45 | 0.92 | 0.12 | 2.03 |
| Wet | 3 | 1.83 | 1.19 | 2.20 | 0.97 | 0.22 | 1.61 |
| Very wet | 4 | 1.14 | 1.03 | 1.28 | 0.86 | 0.38 | 1.32 |
| Average | - | 1.82 | 0.73 | 3.37 | 1.05 | 0.12 | 2.22 |

## Loading

Loading consisted of two operations; chocker setting and winching. Choking time was rather constant and independent of the log size. Winching time was however dependent on log volume, ground slope, winching distance and stump site condition. Equations (7) and (8) can be used for estimating loading time for the crawler tractor and wheeled skidder respectively:

$$LTc = 1.84 - (0.286S - 0.42V) + (0.0061S + 0.0308V) \times WD \qquad (7)$$
$$R^2 = 38.2\%$$

$$LTs = -1.33 + (2.02 + 0.00448WD \times S \times V)COND \qquad (8)$$
$$R^2 = 47.3\%$$

Where LTc = total crawler loading time, min
LTs = total skidder loading time, min
WD = winching distance, m
S = winching slope, %
COND = stump site soil condition

During winching operations, ground slopes varied from 4 to 19 percent and from 15 to 25 percent when using the crawler tractor and the wheeled skidder respectively. The average ground slopes were estimated to be 10 and 20 percent respectively. Studies by McDonald (1972) and Gardner (1979) have shown that the total loading/winching time per load is significantly related to the volume skidded per turn.

### Unloading

Unloading time was independent of the log length and the load size per turn. Unloading time was more or less constant and averaged about 0.73 min. and 0.68 min. per turn for the crawler and skidder machines respectively. (Table 1)

### Effective round trip time

Incase of the crawler tractor, effective round trip time was influenced by the skidding distance, and to some extent by the soil condition and load volume per turn as shown in equation (9). The independent variables considered to have influence on the skidder's effective round trip time were; the skidding distance, winching distance, load volume per turn and the ground conditions (eq. 10).

$$EFFc = 7.11 + 1.12SOIL + (0.024 + 0.00864V)D \qquad (9)$$
$$R^2 = 60.0\%$$

$$EFFs = 13.82 + (-0.718 + 0.088V \times COND)WD + 0.0096D \qquad (10)$$
$$R^2 = 24.7\%$$

Where EFFc = effective crawler round trip time, min
EFFs = effective skidder round trip time, min

### Delay time

Non productive time for the two skidding means constituted a significant proportion; about 40 percent of the total cycle time (Table 1). For the crawler tractor, the delay time was independent of the studied variables. Incase of the wheeled skidder, the delay time increased as the soil conditions became worse. On wet to very wet soils, the wheeled skidder got stuck quite often and the crawler tractor had to pull it.

## Production rate

Despite the skidding distance of the skidder being about four times more than that of the crawler tractor, due to high travelling speed and high manoeuvrability, the production rate was higher than crawler's production rate. This was the case when the skidder was operating on dry and moist soils only. Soil condition greatly influenced skidder production rate indicating that the skidder was more sensitive to changes in soil conditions than crawler tractor. F.A.O (1974) estimates that when skidding with wheeled skidder, during wet periods, production rate can drop to between 65 - 75 percent of the corresponding production rate during dry period. Table 4 shows that due to poor traction, the production rate of the skidder decreased by about 63 percent when operating from dry to very wet soils.

Table 4: Wheeled skidder production rate under differnt soil conditions

| Soil condition | Soil class | Production rate ($m^3/h$) |
|---|---|---|
| Dry | 1 | 14.0 |
| Moist | 2 | 13.5 |
| Wet | 3 | 9.7 |
| Very wet | 4 | 8.9 |

As observed from equation (4), the influence of load size and log length on the skidder's travel time and hence its production rate becomes more pronounced on wet conditions. The skidder load size varied with slope and soil moisture and ranged from 1.41 to 5.80 $m^3$, the average being 3.6 $m^3$ per turn. The recorded maximum loads which the skidder was able to skid at the maximum slope (+25 percent) without winching were; 4.5, 4.0, 3.8, and 2.0 $m^3$ for the dry, moist, wet and very wet soils respectively. In order to optimize skidder's production, it would seem reasonable to buck stems into short logs during the rainy season although too small load sizes would also reduce production rate. Figure 1 shows production rates of the wheeled skidder when skidding varying load sizes under different soil conditions.

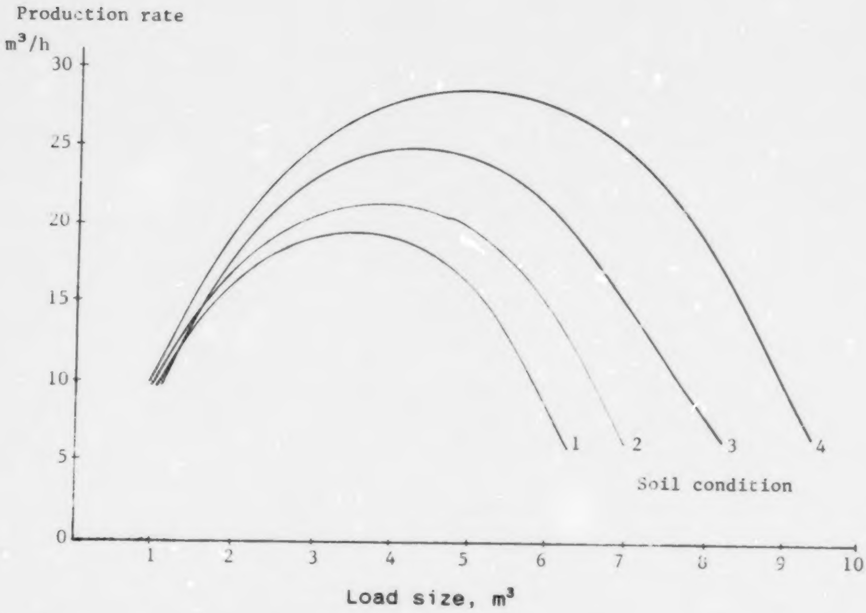

Figure 1: Skidder production rate as a function of load size under different soil moisture conditions

Since the crawler tractor's capacity was not limiting to the load size and neither influenced significantly by the soil conditions, bucking of logs could still continue being undertaken at the roadside landings. The poduction rate per effective hour for the crawler tractor varied from 4.3 to 64.7 $m^3/h$, the average being 15.3 $m^3/h$ while incase of total cycle time, the production rate varied from 1.1 to 59.9 $m^3/h$ with an average of 11.0 $m^3/h$. The production rate per effective hour depended mostly on the winching and the skidding distances while production rate per total time was dependent on the skidding distance only. Equations (11) and (12) show crawler production rates per effective and per total cycle time respectively.

$$PEFFc = 24.0 - (0.04D - 0.14WD) \qquad R^2 = 22.3\% \tag{11}$$

$$PTTc = 15.2 - 0.032D \qquad R^2 = 15.4\% \tag{12}$$

Where PEFFc = crawler production rate per effective hour, $m^3/h$
PTTc = crawler production rate per total cycle time, $m^3/h$

## CONCLUSIONS AND RECOMMENDATIONS

The time study indicated that though the average skidding times for the two terrain transport means were similar, the skidder skidding times were more influenced by independent variables than crawler tractors. Skidder travel times decreased with increasing load size, log length and soil moisture; with delay times increasing with increase in soil moisture. To increase skidder speed, it is recommended to reduce the load size and buck the stems into short logs during the rainy seasons.

Crawler's production rate per total cycle time was mostly influenced by the skidding distance while incase of the skidder, it was influenced by the skidding distance, soil condition and load size. Proper work organization so that crawler tractor is used in the difficult terrains and on wet soils while the skidder works on dry and cleared trails would ensure that the crawler's power and the skidder's speed are used efficiently.

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# APPLYING STEEP TERRAIN HARVESTING TECHNOLOGY TO THE FORESTS OF LATIN AMERICA

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FDC: 311: 945.3: 375.1: (23): (8)

## SUMMARY

Harvesting steep terrain can be more of a challenge than harvesting gentle terrain. By careful investigation and a concerted effort in training and planning, several companies in Chile and Colombia have been able to address the problems of steep slope harvesting.

A program of information transfer through training workshops and field instruction has enabled the industry to successfully shift from ground-based operations to a more cable-oriented approach.

Selection of the correct technique and equipment, after careful planning, are the keys to successful operations. This requires good basic engineering knowledge as well as a concerted effort to transfer technical knowledge to the people involved at all levels.

Keywords: Training, planning, cable logging

## INTRODUCTION

This paper describes a program, instituted by Forest Engineering Inc., of applying engineering technology to the steep forested slopes of two Latin American countries, Colombia and Chile. Subjects addressed are (1) what conditions (terrain, political, and economic) were encountered, (2) how steps were taken to work within these conditions, (3) the progress made, and (4) anticipated future problems.

## CONDITIONS ENCOUNTERED

The conditions found in harvesting the forests of Latin America have changed in the last 20 years in some areas, but in others they remain relatively the same. Two countries that have had some major changes are Colombia and Chile. This paper will concentrate on these two countries, primarily because of the authors' knowledge and because they are good examples of applying steep terrain harvesting technology.

In many of the Latin American countries, harvesting technology goes from one extreme to the other in the use of man-power and equipment. In Colombia much of the road building and maintenance is still done by hand with pick, shovel, and wheelbarrow. Wages are relatively low, and there is pressure by some governments to use manual labor as much as possible. Also, because of governmental import duties, equipment costs can be extremely high.

In both countries many varied systems are being used on steep slopes. These include horses, oxen, chutes, hand carry or shoulder wood, and simply pitching the wood down the hill manually.

Preliminary operations of cutting are similar, regardless of the yarding system utilized. Falling and bucking are normally done with chainsaws. Logs are bucked into 1.2 to 1.5-meter lengths, easily handled by one man. Debarking of pine is done in the bush or on the landing with a machete. The debarked logs are then gathered and stacked into one-cubic-meter bunches for the yarding or hauling phase, depending upon whether the stacking was done in the bush or on the landing. Stacking in the bush is often used as a way to measure production for payment of the workers prior to transporting to the landing.

In the coastal areas of Colombia it is common to forward (swing) the bunches several hundred meters with relatively complex cable systems after the wood has been yarded with a North Bend system or hand-carried to a transfer point. A system most commonly used to swing is the Tyler rigged as a multi-span with a continuous, monocable haulback-inhaul line. The crews working these systems are very well adapted to cable installations. This was one condition that helped when cable operations were applied to the plantation forests of the Andes.

The yarders used in Colombia initially were mostly Iwafuji winches from Japan with some Colombian-built National winches in support. Several Austrian-built Koller smallwood yarders were also present in the early days with more of the new hydrostatic systems being introduced later.

Loading of the pulpwood from these long multi-span cable systems is normally done by hand, although loaders are becoming more common especially in Chile.

The harvesting techniques employed generally in Chile up to the early 1980s were ground-based crawler tractors and rubber-tired skidders as well as oxen operations. Cable systems that were being employed were mostly double-drum highlead units. There was an attempt to conduct helicopter logging operations of cypress from Guaitecas Island in the extreme southern part of Chile in 1980 (Bouchon 1980). The southern region has had long-span cable systems, similar to what is used in Europe, for many years especially in the native forests.

The yarders generally used in Chile were Logger's Dreams built in the United States. These systems had limited reach and, with the highlead techniques being used, were relatively slow. Because of the many ridges and valleys of the coastal forests, the yarders were unable to reach from ridgetop to the valley bottom (Aulerich 1988).

One company, Forestal Carampangue S.A., did have a Madill 071 working near Arauco, south of Concepcion in the Bio Bio Region. Although this model is a highly efficient skyline machine, it was being used mainly in the less productive highlead configuration (Aulerich 1988).

Some of the roads in the coastal region of Colombia and in Chile are normally very good. Modern techniques of road construction using fabric under-layment to reduce rock surfacing, as well as sulfonated oil for stabilization, are common. In fact, some of the roads encountered in Chile were built to higher standards than necessary at much higher costs than were needed.

Excessively large landings were also found in Chile, and a program was instigated in 1984 to reduce the size of landings and roads in some of the areas. Some of the larger landings actually reduced the productivity of the cable systems because of deflection reductions.

Many factors have led to the success of Chile as a major forest products producing region. Just a few will be mentioned here to partially explain why some Latin American countries have been successful while others seem to lag behind.

The Chilean government developed special forestry regulations to help the country's economy in the early 1970s. One that had significant impact on timber harvesting was in forestry, Decree Law No. 701 dated October 28, 1974, which grants a bonus of 75 percent of the cost incurred in forestation and forestry management. This bonus is given only once in a period of twenty years to individuals or juridical entities who invest in new forestry plans (Price Waterhouse 1979). Other programs that gave financial incentives for training also encouraged companies to develop workshops and seminars devoted to improving harvesting and roading techniques in the new forests being developed. Such programs triggered a continuation of a plantation forest industry in the coastal regions of central Chile.

At the same time, the National Forestry Corporation (similar to the United States Forest Service) had been gradually transferring operational activities on plantations to the private sector. The share of governmental control in the total area planted dropped from 30 percent in 1978 to 0.7 percent in 1979.

Another condition that greatly enhanced the success of harvesting operations in Chile was that they have a long established educational system with strong engineering emphasis. The major universities in Santiago and Valdivia both stress basic engineering principles in their forestry programs. This enables the graduates to develop operational plans that meet both social and economic goals. In addition, there are numerous colleges and institutes that give strong basic programs in the technical aspects of growing and harvesting forests. These are located in the smaller cities such as Chillan and Concepcion.

Another event that helped push the forestry program was the First Latin American Forestry Industry Seminar that was held in Santiago, Chile, December 1-4, 1980. This event, organized by the North American magazine "World Wood" and sponsored by CORMA (Corporation Chilena de la Madera, the Association of Chilean Timber Producers), was a success in that it brought together people from different countries and disciplines to discuss harvesting and milling problems. The reason for the selection of Santiago as the location for such an event was that in the eyes of the organizers (Miller-Freeman Publications) Chile was the country with the greatest investment and development potential in Latin America (Olavarria 1980).

After the 1980 symposium, problems such as being unable to access total areas of established plantations, use of low-production systems, and high roading intensities brought on an interest to investigate solutions.

## STEPS IN THE IMPLEMENTATION OF DIFFERENT TECHNOLOGY

### Situation Investigations

The first project conducted by Forest Engineering Inc. was an evaluation of cable harvesting alternatives for INFORSA (Industrias Forestales S.A.) located near Nacimiento, Region del Bio Bio, in 1981. An area to be harvested was evaluated for a small cable system, namely the Koller K-300 skyline system, as well as for a medium-sized system (according to Western United States standards), the Madill 071 skyline machine. At this time there were no Koller yarders in Chile and only one Madill, the 071 previously mentioned.

Roading requirements and projected production rates were evaluated and compared for the study area. Although the smaller tower required more roading than the larger tower (18 percent), lower wage rates and high capital investments made the smaller Koller units the recommended system for operating in young stands. If the wage rate were to increase from a base of $4 (U.S. Dollars) per hour to $15 (U.S. Dollars) per hour, the larger tower would be the choice (Aulerich 1982).

Techniques to improve the productivity of the currently used Logger's Dream yarder were investigated in 1982. A recommendation was made to convert the highleading Logger's Dream yarders to skylining units. This was not difficult because of the design of the machine. The mainline drum is located behind the haulback drum. The conversion did not require any modification, only the systems of rigging had to be changed. The only concern was whether or not the mainline brakes were sufficient to hold the skyline in place.

In a skyline configuration, the skyline (which is usually the largest line) should be above the skidding line to attach to the carriage. Therefore, the only additional expense was to acquire a carriage to replace the highlead butt rigging. A simple, relatively inexpensive Christy carriage was used with the yarder in a gravity configuration.

This simple change in technology has many advantages. First of all, it is much easier and quicker to set up the system since only one line, the skyline, needs to be strung out into the forest in a straight line. The second advantage is that the haulback does not need to go out around the unit, which reduces fire danger from moving lines. The third advantage is that it is much faster bringing logs to the landing since the front of the logs are off the ground, thus reducing the incidence of hangups.

In order to skyline, the location of the yarder and the tailhold are more critical. It is important that management, planners, and loggers are aware of the advantages of such systems as well as the requirements necessary to make such systems work correctly.

Because of the sizes of some of the pine forests in Chile, the Koller K-300 was not large enough for final harvest. Many companies felt that the Madill 071 was too large and unproductive for the price, based upon what they had observed. They were, therefore, looking at a machine that was less expensive (smaller) to do the job. The result was that many companies went to smaller systems such as the Canadian-built Ecologger, the Austrian (South African) Hinteregger, and the larger Kollers such as the K-600. Another unit that was imported was the Ilario winch built in Italy.

Machines larger than the Madill 071 have limited application in the plantation forests of Latin America. But machines of this size and system capability have excellent potential in the final harvest phase. It is unfortunate that they have not had a fair evaluation in the past. The fault is not with the machine but with the application of the machine.

On slopes greater than 40 percent (22 degrees), well-designed cable operations have proven to be less costly than rubber-tired skidders. The key to success is adequate pre-harvest planning and crew training.

A major factor that has helped in the improvement of the use of cable systems in Latin America is that the workers are familiar with using technique (finesse) to solve problems since they do not have the capital to overcome the problems with bigger and more expensive equipment.

## Training Programs

Even with the favorable timber growing conditions present in these countries, a major effort had to be made to train the workers in the use of the new systems. Although many of the managers and forest engineers have a good background in planning and analysis, most of the logging crews are more familiar with manual than mechanical operations. In some areas there is little or no experience with cable systems as used in the United States. This was true of the planners as well as the operators.

Training in the design and use of cable systems included the planning of operations for a given forested area. This meant all roads, landings, and harvest systems were considered as well as the effects these structures would have on the streams and other environmental features.

The effort made to assure well-designed operations for the cable installations was strong in Chile and Colombia in the early and mid 1980s. Forest Engineering Inc. carried out training workshops and investigative sessions for major companies in both countries. Also, the companies sent key personnel to the Forest Engineering Inc. office in the United States to attend advanced training workshops. Five individuals from Colombia and Chile, representing four companies, have also attended an intensive intern program on planning (INPRO) where detailed plans of corporate lands were developed and equipment selections were made.

In Chile, investigations and training were conducted for Industrias Forestales S.A., Forestal Celco Ltda., Forestal Arauco Ltda., and several logging contractors. The first session conducted by Forest Engineering Inc. was in 1981 when a Cable Harvesting Workshop was held in Concepcion. Fifteen individuals from nine different organizations attended. Some of the attendees were from equipment dealers and consulting firms, but most were from timber producing companies.

A training program for crews using the first Koller K-300 was conducted for the Gabrial Diaz H. Corp. in 1981. This two-month effort included the installation of the cable system into the forests of major companies. Training included rigging, equipment operations, cutting, and technique demonstrations of the system. Multi-span rigging and splicing were major components of the technique sessions.

Follow-up workshops in cable systems, harvest planning, and road development were held in 1984 and 1986 for engineers and operations managers of the predominant companies. The importance of pre-planning of larger areas in the steep terrain was the key to this series of offerings.

The primary company in Colombia involved in the training of their personnel in cable logging and roading by Forest Engineering Inc. was Smurfit-Carton de Colombia, Cali (Aulerich, S. P.. 1987). Forest Engineering Inc. held workshops in 1982, 1986, and 1989 and have held field training of yarder setup and rigging procedures on a continuing basis up to the present time.

Intense training of operators followed the classroom sessions in all cases. Rigging of towers and tailtrees, as well as splicing wire rope, were all part of the program. Cutters were instructed in methods of directional falling to improve production of the cable installations. This was especially critical in the thinning operations when small equipment was being used.

## EXISTING OR ANTICIPATED PROBLEMS

### Social and Economic

Most harvesting problems arise from the effort to satisfy the three goals of meeting physical, social, and economic criteria. Since it is impossible to maximize all of these goals, the best that can be done is to optimize. It usually takes some political force to make the selection between social or economic goals.

In the United States on some federal lands, the economics of the harvesting function are secondary to the social environmental concerns. Whether or not this is or will be the case in Latin America remains to be seen, although it is already present in some locales. The question that must be asked is, "Can the country afford to make the sacrifice or tradeoff?" These alternatives will have to be considered now or in the future.

Such environmental considerations may be more important in the native forests than in the plantations. This is already true in large areas of southern Chile and in the interior rainforests of Colombia where native forests are protected from commercial harvesting.

Many of the plantations in Latin America are using lands formerly used for livestock grazing. This has the advantage of enabling harvest planning to be done prior to planting the forest. Such an opportunity should not be lost because it can aid in the location of roads that can be used for planting, tending, and harvesting. Problems associated with planting inaccessible sites can be avoided.

Economic constraints that will have an impact on what systems are affordable are already present from import restrictions imposed on goods coming into the country. What gains may be made from lower wage rates can often be lost due to higher equipment prices.

## Technical

The only criteria that cannot be reduced below a certain level is physical feasibility. We can manipulate the effects of various choices for economic or other interests, but at a final level the physical constraints will determine what is possible. For example, if we are prohibited from rigging through a stream riparian zone because of social constraints, then the production rate may be reduced for a certain system. The system is limited physically due to the constraints we have put upon it. To compensate for the loss in deflection and therefore payload, it may be possible with better knowledge or technique to solve the problem by using tailtrees, multi-spans, or a bigger yarder with a taller tower.

In the plantation forests of Latin America, most of the trees are very fast growing with questionable structural strength. This factor alone could make the use of tailtrees and lift trees used in cable systems an operational constraint. If larger towers were used as an alternative, we may not be able to safely set them up due to inadequate guying anchors.

One company has taken the approach of pre-planning to such an extent that species that are stronger structurally are planted where tailtrees and support trees are going to be needed. Such forward thinking can pay big benefits in the future, but few companies plan harvesting difficulties and solutions 25-30 years ahead (Aulerich 1986). Some research into the strength properties of some of the fast growing species should be conducted to establish safety guidelines for using these trees for support structures.

## RECOMMENDATIONS

All people who influence and direct the harvesting of forests on steep slopes must become aware of the benefits of harvest planning by knowledgeable people. Only in this way can the task of meeting the SOCIAL, ECONOMIC, and PHYSICAL goals be achieved.

Management needs to know how critical the harvest planning process is in the location of roads and in the selection of harvest systems, especially when more complex systems such as cable are being considered. Knowledge brought about by formal education, experience, or training in the subjects of road design, cable logging, watershed management, geotechnical engineering, and basic logging engineering is a must. Management needs to understand what equipment and personnel are capable of doing under various conditions.

The purchase of any major piece of harvesting equipment should not be done until a harvest plan has been developed for the use area. This is especially true in countries that have high equipment costs.

Three major expenditures should be made before harvesting can be conducted on steep terrain. These are for PLANNING, TRAINING, and EQUIPMENT in that order. If these expenditures are not made, then operations should not be carried out in steep difficult terrain.

Managers are not the only ones that should be exposed to harvesting technology. Foresters who are recommending silvicultural practices must realize how their prescriptions influence harvesting. We have already noted how species selection can influence harvesting requirements.

One final word of caution when operating on steep ground that may require cable logging, never road an area without first developing a total harvest plan of the area. First of all, find out the best location for landings and unit boundaries, and then locate the roads to service these landings. If this is not done, the overall road costs will be higher and some areas may be inaccessible.

### Necessary Tools for Planning

We have emphasized the importance of planning but we have not really identified what is needed to do good planning. First of all, the planning must be done by knowledgeable planners who understand the logging systems. This is especially true for cable operations.

Second, they must have the correct tools such as adequate topographic maps. A workable scale is 1:10,000 or better with 10-meter contour intervals. The contour interval should ideally be less than the height of the tower to be used on the ground.

Third, the planners must have an understanding of simple techniques of planning. Some very sophisticated computer systems and models are available to aid in the planning process, but there are many basic manual techniques that can be done without incurring such large capital investments. The use of manual techniques may take longer to do the job but can give comparable results. The key is not the computer programs but the ability to know what they can do for the planner.

In conclusion, it is generally more difficult and costly to harvest steep terrain than it is to harvest gentle terrain. However, if the right techniques and equipment are used, the job can be done while meeting the criteria of being PHYSICALLY POSSIBLE, SOCIALLY (ENVIRONMENTALLY) ACCEPTABLE, and ECONOMICALLY FEASIBLE. It will require knowledge as well as concern by all parties involved.

The Latin American countries described in this paper, namely Chile and Colombia, have an excellent opportunity to continue to meet these goals because they do have the basic knowledge and centers of learning. The challenge is going to be to get management to recognize the need and then complete the transfer of information and necessary techniques out into the woods.

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# STEEP TERRAIN FOREST HARVEST OPERATIONS IN ASIA

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## SUMMARY

Low productivity and economic efficiency, waste of wood, poor road networks, high accident rates, environmental and financial problems are seen as the key issues facing many countries harvesting forests from steep terrain in Asia. Solutions identified were training, improved planning, application of appropriate technology, adoption of an integrated systems approach, and assistance from developed countries.

Keywords: mountain logging, training, multiple-use.

## INTRODUCTION

In many developing countries, forests in the easy terrain have been harvested and converted into agricultural fields to feed large populations. Most remaining forests are growing in remote, steep-terrain areas unsuitable for agricultural purposes. Forest harvesting is being carried out under increasingly difficult terrain conditions. The rapid population growth during the 20th century has led to a constant shrinkage of forests, which amounts to 15-20 million hectares annually in the tropics alone. Although in many developing countries national forestry policies have put emphasis on reforestation, the pace of forest destruction is still several times higher than the annual reforestation rate. In some developing countries, the rapid decrease of forests is already causing a serious shortage of wood for local use.

Forests in mountainous areas have multiple functions. They not only provide timber as a raw material, but also protect such resources as water, soil and the ecosystem. From an overall point of view, the protection functions of forests in mountainous areas are extremely important to humanity. Due to the extensive destruction of forests in mountainous areas, there are a risk of serious environmental consequences such as reduced water supply, decreased agricultural production, increased danger of erosion and flooding, instability of mountain hillsides and adverse impacts on climatic conditions. Effective protection of the Asian mountainous forests, in particular, has become a problem of international significance.

Many developing countries are becoming more interested in developing forest harvesting technology, which ensures not only productive and economic efficiency but also protects the environment and permits sustained exploitation of wood and non-wood resources of the forests.

## CURRENT HARVESTING SYSTEMS

### Forest Roads

For environmental and ecological reasons road network densities should be kept to a minimum. However, a prerequisite for efficient forest management is an adequately established road network which permits the use of appropriate technology for silvicultural tending and harvesting. Many forests in mountainous terrain in developing countries are characterised by a very low density or a complete absence of forest roads. As a result extraction distances are too long e.g. sometimes exceeding 2 km in China.

In steep terrain with difficult topographic and soil conditions, and especially in areas with high intensity rainfall, careful planning, surveying and construction of forest roads needs to be exercised. Established technical road specifications such as maximum gradients, road widths and drainage structures should be adhered to strictly. Full adherence to such standards and constructions methods is not possible in some Asian countries because of the lack of forest engineers who can design, oversee and monitor forest road engineering activities (Balangue, 1987).

### Cutting System

Varying silvicultural, economic and terrain conditions demand different cutting systems. There are no hard rules in favour of either clearcutting or selective cutting.

Clearcutting has an advantage of lowest direct costs in timber harvesting and is therefore quite frequently used in the forests of the temperate zones. During the 1950s and 1960s the prevailing cutting system in the Northeast of China was clearcutting. However, as reforestation - especially for the Korean pine - is very difficult in steep terrain, clearcutting has been rejected. In a number of countries clearcutting is against the law as there is no assurance of proper reforestation.

Selective cutting involves more expensive logging and may damage the residual stand or, indeed, makes it useless altogether. In suitable forests, however, selective cutting, if carried out properly, may result in optimum protection of the environment. Since the 1970s selective cutting has been the dominant cutting system in most areas of China. In protection forests on steep slopes, it is the only permissible cutting system.

### Use of Handsaws and Chainsaws

Although in some industrialised countries mobile felling machines have been widely used,in developing countries the use of handsaws and chainsaws are still a valid option. In a number of developing countries debranching is done by axes. For small to medium trees handsaws, especially the improved one-man bow saws, are quite efficient. In some Asian countries where chainsaws are manufactured locally and there is no need to import from overseas - for instance in China - chainsaws are the major felling tool.

### Free Skidding by Gravity

Felled and debranched logs of 4-5 m are skidded freely downhill by gravity on slopes of 40-60% over short distances. This kind of skidding can create considerable damage to the ground, the log skidded (8-15%) and the remaining stands. Free skidding by gravity is still used in Southern China and other Asian countries, usually as a pre-extraction followed by a secondary extraction.

### Skidding by Gravity by Chutes

Skidding by wooden chutes has been the traditional harvesting method in China for more than 200 years. On steep slopes crosstie chutes are constructed while on moderate slopes lengthwise log chutes prevail. Logs are transported by chutes over distances of from 200 m to 1000 m on slopes of 45-60% in Southwest China. Ground and log damage has limited the application of wooden chutes. A study has been undertaken on the possible application of polyethylene chutes for thinning operations in plantation forests in the Republic of Korea. The skidding distance is about 150 m to 300 m with slopes of 25 to 55%. For a 100 m chute setting in a seven-year-old pine stand a productivity of 0.7 cu.m. per man hour has been achieved with four men. Extraction costs amounted to some US $ 6/cu.m (Heinrich, 1988).

## Manual Skidding

Manual logging in the Far East was common in the past. In fact, the pulling of logs by a group of men was widely used e.g. in Indonesia it was called kuda-kuda logging. Even today, the cart or wheelbarrow is widely used for forwarding logs after skidding by gravity. In Southern China it is called "manshanpao" (means can drive everywhere). The average load is about 300 kg to 500 kg.

## Animal Skidding

In some countries including those where specialised high-productive logging machinery has been introduced animal power is still used successfully and economically. Logging with elephants is well established technology in several countries such as Burma, India, Sri Lanka and Thailand. Extraction with oxen, horse and buffalo is still common in China, India and the Philippines.

Animal skidding is more cost-effective under some conditions and is feasible in environmentally sensitive areas. It causes less damage to the ground and the remaining stand. In northeastern China, where the mechanisation of forest operations is more developed, animal skidding is still used in the winter taking advantage of ice and snow cover on the ground. The logs are skidded down hill, with the front end of the logs fixed on a simple sledge and the rear end dragged on the ground. Oxen and horses can negotiate slopes of up to 50%. Productivity of animal logging varies considerably depending on the type of forest, size of logs, terrain, soil condition, breed and health of animals, as well as training of drivers.

## Agricultural Tractor Skidding

One of the machines which has proved to be particularly successful in forestry operations is the agricultural tractor equipped with forestry attachments. Such attachments include single or double drum winches, logging trolleys, cable equipment, semi-trailers and trailers.

Although the agricultural tractor is well known in most of the European countries it has not won the same popularity in developing countries for log extraction. In some industrialised countries the number of agricultural tractors used in logging exceeds by ten times the number of skidders or other specialised logging equipment. A prerequisite for the efficient use of agricultural tractors in mountain forestry is an adequately developed forest road and skid trail system. The main factors which limit their use are terrain and soil conditions, the size of trees and difficult access. Agricultural tractors can negotiate slopes of no more than 25%. In southern China, agricultural tractors with semi-trailers are widely used for forwarding short logs after gravity skidding. Agricultural tractors are also used in logging in Viet Nam.

## Skidder Extraction

Specialised skidders have considerable advantages over agricultural tractors. Skidders have better maneuverability and can easily travel in the woods. They can negotiate steep slopes up to 50%. The front end of skidded logs is lifted off the ground by special winches and bunk or arch which are fitted to both crawler and wheeled skidders. This make skidding more productive. Wheeled and crawler skidders are the most popular machines used in mountainous forests in Asia.

Tractor skidding has been preferred for more than 35 years in northeast China; the most popular skidder being a J-50 crawler powered by a 50 HP diesel engine through a five speed transmission. Equipped with a single drum winch frame and frame bunk on the rear, which can be raised and lowered hydraulically to carry the front end of the tree-length off the ground, the J-50 is specially designed for skidding in forest terrain. The flexible carrier can automatically adjust to terrain conditions and travel in the wood easily. It has a skidding capacity of 5 to 8 cu. m. Another skidder used in the northeast forests in China is J-80, a 4-wheel drive skidder which is equipped with a 80 HP diesel engine and ten speed transmission, as well as bunk and winch. This articulated machine travels much faster and is often used for long distance skidding on moderate terrain (less than 30%). Both crawler and wheeled skidders use chokers to attach tree lengths to the winch cable. Logs are usually skidded downhill to the valley floor, where the forest roads are located.

## Use of Self-loading Winch Trucks

The winch lorry system is not new in tropical forests. It was first introduced 40 years ago in Malaysia and has recently been revived, spreading to many more countries, for instance Viet

Nam because of the considerable increase in prices of other machines.

The original concept of the winch lorry is that a secondhand six-wheel-drive truck is converted into a logging vehicle by equipping it with an A-frame or a heavy duty loading frame, a winch and removable sidebunk. When a truck is adapted in this way, it can perform three functions: loading, skidding and transport. Under favourable conditions winch lorries can be used on slopes up to 30% and on even steeper slopes for downhill transport.

This equipment is fairly easy to use, simple to operate and maintain; it can normally be obtained inside the country, and is inexpensive. A time and work study of a 12-ton Isuzu winch truck in Viet Nam revealed that loading for an average load of 10.2 cu. m. amounted to 42 minutes with transport costs of US $13/cu. m. for a distance of 60 km. It is used successfully by small contractors in natural forests in many developing countries. It is usually less expensive but requires a higher labour input than specialised logging equipment.

## Cable System Yarding

In North America and in Europe, the mobile yarder and grapple yarder have made considerable advancement in cable yarding. The rigging work has been reduced significantly. The productivity of cable yarding is getting more attractive, and the manpower required has been reduced to a minimum.

These systems, however, are still too advanced for many developing countries due to social-economic and technical reasons. One example is the Steyr mobile yarder introduced in China in 1987. The machine costs twenty to thirty times more than the domestic winch, while productivity is just two or three times higher.

The simplest of all the cable systems is the gravity skyline cable system. The cable equipment is composed of a single drum or double drum winch, a skyline, a mainline and a carriage with or without a built-in stopping device. All winches are mounted on sledge logs and powered by engines ranging from 25 to 50 kw. The setting up of such a system requires a survey of the skyline corridor and the selection of appropriate spar trees as well as support trees if the cable system is a multi-span one.

Generally, these gravity systems have a yarding distance of 500 to 1500 m and logs can be dragged in 25 to 30 m from both sides of the skyline. For instance, in Bhutan, Pakistan and China, when using a single drum yarder of 50 kw and a 25 mm skyline of 1000 m and a carriage of 2.5 to 4 tonnes, a daily productivity of 20 to 30 cu. m. has been reported.

The gravity cable system can be used to pick up logs at any point along the skyline as well as a means of linear transport, substituting partly for a road network system. The latter case was successfully introduced in the Himalayas in Pakistan to overcome extremely difficult terrain in order to transport logs from a high plateau (Stohr et al. 1988).

Gravity skyline systems have the least negative impact on the environment, as the logs are either partially or fully suspended off the ground. In environmentally sensitive areas, the skyline system is the more acceptable extraction method. However, because of the complicated, and time-consuming, rigging and installation procedures, the setting up time of a gravity cable installation takes generally two weeks.

The high lead system is used to transport timber to the road side in a few countries, such as the Philippines, Indonesia, Malaysia and China. Usually a spar tree is rigged and logs are dragged uphill or downhill a distance of 300 m. Although the system requires a relatively low capital investment and is simple to operate, its main drawback is the negative impact of dragging logs on the soils - causing erosion on steep slopes. In recent years, the use of the high lead system has declined.

## EXISTING PROBLEMS

The existing problems could be split into the following categories: technical, environmental and financial.

### Technical Problems

#### Low productivity and economic efficiency

Due to the lack of trained personnel, the productivity and economic efficiency of forest operations are very low in developing countries. For instance, even in northeast China where forest operations have been mechanised, productivity is only 260 to 290 cu. m. per man per year.

#### Waste of wood

The short wood system, where most logging residuals are left in the wood unutilised, is the prevailing harvesting system in most developing countries. Some harvesting operations are primitive and there is a lot of waste. Logs have to be rolled and converted to cants prior to free skidding on steep slopes.

This can cause serious damage to the logs which amounts to a loss of 8 to 15% log volume.

### Poor road network

Many forest areas, especially mountainous areas in developing countries, are characterised by an absence or a very low density of forest roads. For instance in northeast China, in the most developed forest region of the country, the density of the forest road network is only 7 to 10 metres per hectare; that results in extremely long skidding distances. Forest roads are essential not only for log hauling, but also for all forestry activities. In some remote areas forest roads play an extremely important social development role.

### High accident rates and poor safety

As a rule, the accident rate in forest operations is relatively high in most developing countries. Safety and ergonomics are often neglected due to the low living standards.

## Environmental Problems

Severe damage to the environment is often caused by the application of improper forest operations in steep terrain. In some regions, the forest never returns after harvesting due to the difficult physical conditions for regeneration. The loss of the forest environment means much more than the loss of a potential wood source. Badly located and poorly constructed and maintained roads and skid trails lead to land slips, siltation, and local flooding which greatly degrade the environmental protection efficiency of the forest.

## Financial Problems

Adequate finance is an essential requirement for all activities in a country, including forestry activities. Many developing countries lack funds which are necessary for training personnel, developing road networks, replacing equipment, and planning forest harvesting.

# SOLUTIONS

## Training

Not enough people with the appropriate skills is one of the biggest problems faced by many developing countries in Asia. Training at all levels has been identified as a major need. Training needs to take place at planning, operational, managerial and university education levels.

### Planning

There are some good examples of training courses which rapidly raise the skill levels of harvest planners. The Forest Engineering Institute course run by Oregon State University in Corvallis, Oregon, USA has been taught for over a decade. Although the course is predominantly for US government employees representatives from other countries have been trained at the Oregon FEI course. Recently New Zealand has developed its own version of an eight-week New Zealand FEI course modelled on the Oregon course. Course participants cover topics such as forest roads, log transport, work study and system productivity, economic evaluation, cable logging systems, ground-based logging systems, soils and hydrology, forest engineering computer software, and plan preparation. Careful application of forest engineering techniques will help minimise environmental problems. It has been repeatedly shown in other parts of the world that better planning and design of logging systems and tight implementation of those plans can also raise productivity and reduce costs substantially, compared with the deceptively more convenient, traditional methods (Kerruish, 1983).

### Operational

Some developed countries, such as Sweden and Finland, have well established operational training schools for forest harvest machine operators. The students at these schools are taught how to operate and maintain very sophisticated machines. Other developed countries, such as New Zealand, encourage on-the-job operational training - which is monitored and coordinated by a Logging and Forest Industry Training Board - in safe and efficient work methods. Other technical skills, such as surveying, also need to be taught.

### Managerial

Supervisors and managers will need to be trained to ensure that full benefits of the harvest planning are implemented. These people will need an understanding of the systems to be implemented, including the information that would be covered in the FEI courses mentioned above. Additional knowledge of market requirements, business management and organisational skills, negotiation skills, and people management skills would also be required. In New Zealand courses covering these topics are often taught at Polytechnic Institutes.

### University education

It is important that forest harvesting be recognised as a field of knowledge worthy of research and teaching at the university level in Asia. A recent "Review of forest management systems of tropical Asia" noted that conventional forestry education and training was not well-equipped or motivated to provide the highly skilled motivated and experienced staff required for planning and supervision of logging operations (FAO, 1988). Short term solutions to training and other harvesting problems may come from outside Asia but the regional Asian universities in the long-run most provide the solutions. The world respected undergraduate and graduate forest engineering programme run by Oregon State University is an excellent model to follow.

## Improved Planning

The planning process is an analytical process which encourages the consideration of alternative options for getting the harvesting job done within the constraints imposed. It is the planner's role to identify, in a quantitative manner, the options which make the best use of the resources available or to identify important resources which may be missing, e.g. the right machinery or the right people. As more harvest planners are trained improved harvesting and transport planning will follow.

The cost of good quality planning is repaid many times over. The benefits that could be expected from improved planning would be - better road and transportation systems, lower harvesting costs, safer operations, higher productivity and more environmentally acceptable operations.

Maps are the basic source of information for detailed harvest planning. Improved planning will require that people with the skills for providing good quality maps are also available. The use of Geographical Information Systems, which incorporate qualitative and quantitative spatial map data, will help to plan and manage logging operations better. GIS will also assist the forest manager to better record and give attention to timber inventory and resource assessments, topographical and watershed values, wildlife, and other products of commercial value.

## Application of Appropriate Technology

Technology which is appropriate for one country or region may not be appropriate for another. Many different harvesting systems have been developed around the world - some of them employing basic logging technology, others employing highly mechanised systems. Each country must adopt the harvesting technology most suited to its existing social, economic and physical conditions. The development of such technology must take full advantage of resources which are in abundance and, therefore, comparatively cheap in the country concerned.

Many developing countries in Asia are characterised by:

- ample availability of cheap labour
- high machinery costs (both purchase and operating costs)
- shortage of foreign currency
- lack of funds for forestry activities and road building
- shortage of energy
- shortage of skilled machine operators and technicians
- lack of maintenance and repair facilities for equipment and advanced machinery.

Heinrich (1986), in an FAO publication on "Appropriate wood harvesting in plantation forests", notes that "In developing countries, it may be more sensible to upgrade existing technology, improve work organisation and apply proper safety concepts, thus reducing accidents and risks to health. It may be advantageous only at a later stage gradually to introduce a higher technology".

Unfortunately even today highly mechanised harvesting systems are still transferred mechanically from industrialised countries to developing countries. In many cases in fact the mechanical transfer of such sophisticated technology is not only uneconomic but also antisocial and antiecological.

## Integrated Systems Approach

Forests in Asia have a strong multiple-use demand on them. The interaction of non-wood forest products and wood production under a sustained yield forest management concept requires that an integrated approach to forest management is adopted. The importance of forests in supplying non-wood forest products such as water and soil protection, honey, nuts, mushrooms, medicinal plants and wildlife needs to be considered when decisions are being made about wood harvesting operations.

When harvesting systems are being selected it is important to consider the benefits as well as the costs of alternative options. Stohr et al. (1988) provide an example of a comparison between traditional and improved forest management systems in Pakistan. The table shown below is reproduced from their paper. When a systems approach was taken a net benefit of US $ 70.83 per cubic metre accrued to the improved method, even though roading, harvesting and transport costs were all higher.

Table 1: Comparison between traditional and improved forest management systems (Source: Stohr et al. 1988)

| Criteria | Additional revenues USD/m3 | Additional costs USD/m3 |
|---|---|---|
| Positive aspects | | |
| Less felling losses (5% vol.) | 10.5 | |
| No felling losses (10% vol.) | 20.0 | |
| No loss due to making cants (5% vol. of 15% of log vol.) | 17.6 | |
| Higher prices | 40.0 | |
| Regular employment | | |
| Training of workers and higher living standard | | |
| Better protection of areas under regeneration | | |
| Less damage to remaining crops | | |
| Less impact on ecology with cable systems | | |
| Better management through more roads | | |
| Negative aspects | | |
| More roads are required | | 1.40 |
| Maintenance of existing plus new roads | | 5.29 |
| Increased harvesting and transport costs | | 10.59 |
| Ecological disturbance by road construction | | |
| Total | 88.11 | 17.28 |
| Balance | 70.83 | |

## Assistance from Developed Countries

Harvesting of the mountainous forests of Asia must be seen to be a problem of worldwide significance if done poorly. In our opinion the best way that the international community can assist is by providing assistance in training logging planners and managers - to give them the forest engineering and land-use management skills needed. The assistance could take the following forms:

- encouraging IUFRO to hold more technical seminars in Asian countries
- encouraging the formation of technical groups in Asia similar to the North-American based Council on Forest Engineering (COFE)
- sponsoring short intensive courses at appropriate locations inside Asia
- providing scholarships for students to attend short intensive harvesting courses and gain work experience at locations outside Asia
- providing scholarships for Asian university staff to maintain and update their skill level at overseas universities
- providing scholarships for university staff from other countries to teach or carry out research at Asian universities.

## CONCLUSION

The rapid decrease of forest resources in Asia deserves special concern. Harvesting of the mountainous forests in Asian countries is to be seen as a problem of worldwide significance if done poorly. International organisations, such as IUFRO, FAO and others, have a responsibility to help ensure that forest operations in these countries, especially in steep terrain, be carried out right. The developed countries can assist through various training mechanisms to ensure that appropriate skills are developed as soon as possible.

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# FOREST OPERATIONS ON STEEP TERRAIN IN AFRICA

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## SUMMARY

In introducing the paper, attention is drawn on the importance of sustainable forest management, particularly on steep terrain, to support agricultural development and thus contribute to food security.

Innovative approaches are described in planning, surveying, road design and environmentally-oriented road construction, including protection engineering works to open up mountain forest resources.

The paper also deals with the importance of the use and transfer of appropriate harvesting technology to meet social and environmental requirements. Several systems are briefly mentioned with emphasis on labour-intensive, basic and intermediate technology.

Information is provided on a recent FAO survey on harvesting training needs in 12 African countries which revealed a considerable shortage of training facilities, particularly at the vocational level.

Keywords: environmentally-oriented road construction, appropriate harvesting, transfer of technology, training.

## INTRODUCTION

In many countries in the African Region, forests constitute an important renewable resource which, if managed on a sustainable basis, could contribute significantly to the overall development. Yet the reduction of forest land and degradation of forests have reached an alarming proportion which has raised public concern and requires a concerted action to ultimately stop and reverse this trend.

FAO therefore has launched the Tropical Forestry Action Plan (TFAP) which is a coordinating mechanism to save and restore forests and forest lands, as well as promote their sustainable use. The Tropical Forestry Action Plan consists of five priority areas which are: forestry in land use, forest-based industrial development, fuelwood and energy, conservation of tropical forest ecosystems and institutions.

The main causes of deforestation are the increase in population, inequitable land distribution as well as unsuitable development and settlement schemes. Environmental stability is particularly important in sub-Saharan Africa as well as in the mountainous areas. Poor land use practices and excessive cutting of fuelwood and timber on hillside forests have a devastating effect, causing severe erosion, flooding and siltation in lowland areas, increasing insecurity in food production and malnutrition. As the population approximately doubles every 24 years in Africa, increased efforts are required to conserve forest lands, improve management and utlization of forest products, particularly on steep terrain, not only to provide the necessary raw material but to support agricultural development and thus food security.

## IMPORTANCE OF MOUNTAIN FOREST ECOSYSTEMS

The importance of the preservation of mountain forest ecosystems is widely recognized, particularly to provide protection of the soil against erosion and siltation, maintain waterflows throughout the years, supply raw material to local populations and forest-based enterprises and support rural and overall economic development.

With the increasing population more pressure will be exerted on forest lands, leading to land clearings and exaggerated use of forest products.

Particular attention will have to be paid to increase efforts in maintaining forest resources on steep terrain, refining management and harvesting practices and also satisfying the needs of people who live in and around the forests. One country which particularly experiences the severe effects of deforestation, causing poverty and malnutrition, is Ethiopia. At the beginning of this century, 40 percent of the land area was covered by forests, which now have decreased to only 4 percent. The impact of erosion has already considerably reduced agricultural productivity but, if not checked, it will rise five times, destroying farmland of an estimated 10 million people by the year 2010.

One major step in promoting intensified mountain forest operations will be to involve local people to a larger extent through labour-intensive activities in reforestation, silvicultural treatment, harvesting and infrastructure development, thus providing them with employment, income and direct social benefits.

Intensive management will certainly also raise the yields per unit area, which in many instances can be increased by as much as 50 percent. A further possibility in improving utilization would be the introduction of appropriate environmentally-sound harvesting systems, reducing the waste in the forests. In mountainous terrain, forests often, besides their economic value, have to serve primarily as protection or recreation reserves.

## OPENING UP OF MOUNTAIN FORESTS

With the introduction of modern forest management and harvesting techniques, the opening up of mountain forests by means of forest roads has become a necessity. Appropriate road layout, design and construction techniques have to be applied to minimize the negative environmental impact of roads. In many countries, forest roads not only serve for forestry purposes but also enable local populations to have easier access to markets and thus contribute to the social and economic development, particularly for rural communities in remote hillsides. Often road nets are insufficiently developed, ranging from some 5-10 m/ha. For forest management purposes, in general, a road net density of 25 to 40 m/ha can be considered optimal. Depending on the planned or introduced harvesting system, additional skid roads or tracks may be required. In environmentally sensitive watershed forests, however, forest roads may need to be substituted partly or totally by long distance cable transport systems often ranging from 1000 - 2000 m length. Such a transport system has been put in place in Malawi for transporting timber, material and agricultural products from and to the Mulanjee mountain plateau.

With the introduction of efficient road construction, the use of machinery such as track type tractors and loaders as well as hydraulic excavators, opening up mountain forest resources, has been facilitated considerably. In developing countries with low salary levels, however, careful evaluation has to be made using labour intensive, intermediate or capital intensive roading techniques. In any case, in line with the increased efforts in road development, enhanced manpower training will be required in planning, surveying and design of forest roads. FAO, for a number of years, has attached great importance to this subject. Within the framework of international courses and seminars, a regional training course on appropriate wood harvesting in plantation forests was held in Zimbabwe in 1986, at which participants were advised on mountain road development issues and carried out practical field exercises in road location. Similar courses were organized by the Forestry Training Programme of Finland in Zambia in 1979 and in Kenya in 1980.

## Planning and Surveying

Road planning has to take into account present and future uses of the resource base, including all related management practices, considering the most efficient service and minimizing financial and environmental costs. Computerized optimization models have been developed to derive at optimum solutions, minimizing road and extraction costs. Planning optimal road nets is however not only important for minimizing construction and transportation costs, but considerations have to be given also to yearly maintenance costs and the reduction of productive forest land which, on steep terrain, due to large cut and fill slopes, can be very significant.

The basis for planning well located roads is topographic maps with scales of 1:25 000 or 1:50 000 with vertical contour intervals of 20 m, as well as aerial photographs and forestry maps preferably with scales of 1:5 000 or 1:10 000. Planning road lines thoroughly will involve considerable field work comprising field reconnaissance work, preliminary surveys, determining alternative route locations and finally selecting the most appropriate routing. The following material and instruments have proved most useful in road locations: aerial photographs, topographic and forestry maps, pocket stereoscope, barometric altimeters, clinometers, compasses, engineer tape or drag rope, range rod, engineering notebook, flag tapes, stakes, pencils and crayons. A forest road specialist, with four to five workers, can normally survey a road line of 0.6 to 1.0 km per working day.

## Road Design

The road design and layout very much depend on terrain, soil, climatic and forest conditions as well as on the existing and envisaged traffic requirements, taking into consideration vehicle characteristics. Often, appropriate gravel material for the base formation is not easily available; therefore, roads can only be used in dry stage, when having a sufficiently strong bearing capacity permitting traffic of heavy duty vehicles. In many instances, on steep terrain, single-lane roads with visible turnouts every 250-300 m may suffice. Careful evaluation is required to justify double-lane roads vis-a-vis environment, construction costs and traffic needs. One important aspect when planning roads is to realise that the road cut slope and part of the adjacent road surface can be most useful for small-scale landing operations, especially when using mobile cable systems. Based on experiences in various countries, Table 1 provides some suggestions for road classifications on steep terrain.

Table 1: Road classification

| Road type | Road use | Road formation width (m) | Carriage-way width (m) | Maximum gradient in transport direction (%) | Maximum gradient in adverse direction (%) |
|---|---|---|---|---|---|
| Main forest road | Truck, pickup, permanent | 5.0 | 4.5 | 9 | 6 |
| Secondary forest road | Truck, pickup, temporary | 4.5 | 3.5 | 10(12)* | 8 |
| Skid road | Wheeled skidder, wheeled tractor, crawler-tractor | 3.5 | - | 12(20)* | 10 |

( )* Maximum gradient for short distances only.

## Environmentally-oriented Road Construction

In mountain forest road construction, normally light to medium crawler-tractors (15-18 tons operating weight), are employed. On steep terrain, due to environmental considerations, however, it is recommended to use hydraulic excavators.

The excavator is a very versatile machine, permitting careful removal of earth material and depositing it at the side slope, formation of a sound road base, shaping of cut and fill slopes, placing of culverts and constructing efficiently stone retaining structures.

When locating roads on mountainous terrain, the engineer generally tries to locate most of the road base on the cut slope, leaving the remaining part on the fill slope. When roads have to be constructed on side slopes steeper than 70 percent full bench roads have to be constructed. One possibility of reducing excavation and transport of soil material is to construct retaining walls made of rocks, gabions or log cribs.

In some African countries with plenty and low-cost available manpower, however, remarkable results in labour-intensive road development and related forestry projects have been achieved through food-aided projects. Depending on soil and terrain conditions, productivity of earth moving by manual labour can range from 0.3 m³ to 1.0 m³ per manhour. For productivity reasons, length wise earth movement should be restricted to 30 m.

## Drainage Facilities

In many instances poor drainage facilities of forest roads are a major source of erosion caused by excessive water or moisture. The drainage system must allow to drain off efficiently surface and subsurface water, taking into consideration natural drainage patterns. Properly designed mountain roads generally are provided with mountain side road ditches, culverts with protected in- and out-lets and, if required, with fords and bridges. To drain off road surface water earth cross drains as well as open top culverts at appropriate spacing and with a cross gradient of 6-7 percent are placed in the road.

In many countries, various types of open top culverts have been developed and introduced, made of locally available material which could be small-sized logs, combination of logs and timber or timber only.

## Road Protection Engineering Works

In stabilizing slopes and gullies a combination of structural mechanical engineering works and revegation measures will be most effective. Various designs of retaining structures such as gabions, stone walls, log or precast concrete crib revetments, reinforced earth works, etc. are in use in numerous countries.

For low cost roads, building material must be selected close to the construction site. Inexpensive structures such as gabions which can easily be set up with proper supervision by unskilled labourers have proved to be effective and to integrate well in the environment. From various observations made it was noted that two mandays were required to construct one $m^3$ of gabion. The work comprised preparation of wire mesh, collection of stones near the construction site, transport and setting up the stones as well as rock fills. To protect slopes from surface erosion, seeding, and many times also planting of brush layers, are applied. A technique often used is called contour wattling, which essentially consists of driving stakes into the soil and placing cuttings or rooted plants into contour ditches. When applying contour wattling with a vertical spacing of 1.5 m, and putting in stakes at 50 cm intervals, as well as putting in bundles of cuttings with a diameter of 15 cm and 3 m length, a ten-man crew can carry out rehabilitation work on an area of about 250 $m^2$ per day.

## Road Maintenance

Road maintenance is required to permit efficient and safe use of the road and prevent a negative impact on the environment. Regular maintenance schedules should foresee inspections of road structures, drainage facilities and conditions of road surface.

In general yearly road maintenance costs can amount to 3-5 percent of the construction costs; under extreme terrain and weather conditions it may however be higher. Road maintenance costs can be kept minimal on roads properly designed and located (3 percent minimum and 9 percent maximum gradient) as well as closing off roads during heavy rain periods. For road maintenance manual workers can be ideally employed.

## NEW DIMENSIONS OF FOREST HARVESTING

FAO's perception of forest harvesting in relation to socio-economic development has gone through a substantial evolution. In forestry, a concept which needs to be more frequently introduced is the use of a wider range of forest products based on a sustainable resource management. In addition to timber, a multitude of non-wood products are available from the forests which can be most beneficial in terms of employment and income generation, particularly for the local population. In many instances, harvesting therefore is no longer synonymous with logging as it deals with a wide array of non-wood outputs. A partial list of such products may include plants for ornamental and medicinal use, honey, resins, tannins, fruits, mushrooms, nuts, wild life for food and hunting trophies, etc. Harvesting therefore may be defined as the procurement of raw materials from the forests. When recognizing this new approach, harvesting is no longer an independent technical discipline but has to be seen in an integrated concept forming a strong link between the resources, forest-based enterprises and markets. FAO, besides its traditional work in wood harvesting, has recently developed an action programme on harvesting of non-wood products and has undertaken case studies on small-scale harvesting of non-wood products with strong people's participation published as FAO Forestry Paper No. 87.

## TRANSFER OF APPROPRIATE TECHNOLOGY

The availability of a wide range of specialized harvesting equipment requires a careful evaluation and selection of equipment and systems which are suited to the skills of the workforce, meet the environmental and social obligations and are appropriate to the specific harvesting jobs to be carried out.

FAO can assist to bring improvements by providing technical information on harvesting systems and equipment, advising on planning and executing forest operations and by organizing training courses on all aspects of raw material procurement. In this context a computerized information system has been established on forest harvesting machines, which contains data on some 240 manufacturing companies to better serve member countries in their development efforts. In addition, a number of case studies were undertaken to support development efforts in harvesting. Three of these case studies were carried out in Ethiopia, Tanzania and Zimbabwe, dealing with small-scale raw material procurement and processing.

One of the major problems to overcome is the lack of adequately trained manpower at all levels, including the manager, supervisory, technical as well as foreman and worker level. This will require increased efforts in establishing new and/or strengthening existing harvesting training programmes at educational and training institutes. While in the past often the economy of scale favoured large-scale operations with capital intensive technologies, it now appears that there is a more realistic approach in solving harvesting problems, considering various combination of machines and level of sophistication. Basic and intermediate technologies have been rediscovered as valid options, particularly in small-scale operations. Often, however, it appears that there is a lack of institutional ability in promoting such activities. For example, quite frequently it is difficult to obtain credits and government support as small-scale projects have less political appeal than large-scale prestige projects.

## Wood Extraction by Gravity

Before the development of specialized harvesting machines the use of gravity force in mountain logging operations was the major mode of moving logs. The use of flumes, log chutes, wires and hookeroons were useful applications to harvest a tract of timber on steep terrain.

One recent development which could be of interest in early thinning operations in plantations requiring silvicultural treatment is the development and use of U-shape polyethylene chutes. FAO has undertaken a pilot study in pine plantations were posts, pulpwood and small-sized saw logs up to a maximum diameter of 30 cm were transported. The use of such chutes can be favourably applied on slopes of 25-55 percent and for distances ranging from 100 to 300 m. In a seven year old pine stand, for a 100 m chute setting, a productivity of 0.7 $m^3$ per manhour has been achieved when employing four men.

## Use of Animals

The use of animals in wood extraction and transport often forms part of a transport system or can stand on its own, particularly in small-scale operations.

FAO has carried out a number of studies on the feasibility and limitations of employing oxen, mules, horses and buffaloes for transporting smaller sized logs in plantation forests. In many instances animal logging, especially for short distances, compares favourably with motor mechanical extraction systems. As a matter of fact, in recent years, an increased interest has been noted in using animal power to transport wood in a number of countries, also in Africa. A country which has quite a long tradition in using oxen for wood transport is Malawi, where in the mid-seventies an oxen logging training centre was established and the transport of sawlogs by oxen is applied successfully. In oxen skidding, average load sizes per pair of oxen tend to be 0.4 to 0.7 $m^3$ with maximum pay loads of up to 1.7 $m^3$. When transporting heavier loads, however, it is advisable to use auxiliary equipment such as boogies, wagons and simple sledges. Oxen can negotiate on slopes of up to 30 percent, when pulling logs downhill. When using manual or a combination of manual and animal extraction methods, coordination of operations can be quite a difficult and complex task to guarantee a continued wood supply to large-scale industries. Table 2 provides some examples of productivity in oxen logging in Malawi and Tanzania.

Table 2: Examples of productivity in oxen logging

| Country | Stand | Operation Volume removed | Terrain | Load | Productivity over a distance of 100 m |
|---|---|---|---|---|---|
| 1. Malawi | Pinus patula<br>16 a | 2nd thinning<br>40 m³/ha | Downhill<br>35-45 % | 0.38 m³<br>(4 logs) | 1.5 m³/hour |
| 2. Malawi | Pinus patula<br>30 a<br>(bigger logs were extracted by means of a bogie) | Clearfelling<br>450 m³/ha | Downhill<br>9-21 % | 0.33 m³<br>(1 log) | 2.7 m³/hour |
| 3. Tanzania | Pinus patula<br>16 a | | Uphill | 0.18 m³ | 1.3 m³/hour |

## Ground Dependent Logging Machines

Terrain and soil conditions are the main limiting factors for the use of ground dependent vehicles, such as agricultural tractors, wheeled and tracked skidders as well as crawler tractors and winch trucks. Table 3 presents some slope limits for selected logging machinery based on the experience in a number of countries.

Table 3: Indicative slope limits for selected ground dependent logging machines

| Type of machine | Slope limits (in %) |
|---|---|
| Agricultural tractor | 20 - 25 |
| Winch truck | 25 - 30 |
| Wheeled skidder | 35 - 40 |
| Tracked skidder, crawler-tractor | 40 - 50 |

### Agricultural tractors

Agricultural tractors, if equipped with appropriate forestry attachments, can be most valuable in forest work, providing the farmer with additional income. Limitations of use however require that logs should not be bigger than 1.5 - 2.0 m³, the ground must be firm and slopes not steeper than 25 percent. It can be best used in plantation forests or natural forests with medium sized trees. Agricultural tractors used in forestry work should be equipped with four-wheel drive, roll-over protective structure, three-point linkage, power take-off, bottom shield and a minimum power source of 35-65 kW. Skidding productivity can vary from 3.5 - 7 m³/hour for distances of up to 400 m.

Depending on the attachment, which can be grapples, winches, trailer cable equipment, the agricultural tractor can be used for wood extraction, winching, road or cable transport.

## Skidders and crawler-tractors

Specialized extraction equipment has been developed to facilitate wood extraction from the stump site to the road. These machines can be used under a wide range of conditions, particularly on swampy and soft soils as well as on steep terrain of up to 50 percent slopes. Sizes and power of machines vary considerably. In thinning operations, one employs small-size skidder with 20 kW whereas in plantation forests with middle-size trees skidders with 65 kW and in tropical high forest timber stands skidders with 130 kW. In tropical high forests often a combination of crawler-tractors and skidders are in use for wood extraction and skid road formation.

In skidding operations, normally, average skidding distances are ranging from 400 to 1 000 m, with average loads of 7 - 10 m³, when employing heavy duty skidders.

## Winch trucks

The original concept of the winch truck was to convert a second-hand six-wheel drive truck into a logging vehicle, equipped with an A-frame or a heavy duty loading frame, a winch and side bunks. When equipping a truck in this manner, the vehicle can perform three functions, namely skid, load and transport. This system is favourably used by individual contractors in small-scale and relogging operations or where harvestable wood volumes are as low as 10 m³/ha. In mountain forests the winch truck can be employed on slopes of up to 30 percent for downhill transport. In recent years, the Isuzu company has commenced to produce logging winch trucks. The advantage of the winch truck system is its low capital investment and the versality of its operation. Under very difficult conditions, however, a crawler-tractor may be still required as a primary mover.

## Cable logging systems

The use of cable logging systems in most of the African countries is still rather exceptional, as it requires considerable investment, skill in planning and operating the systems. From the environmental, silvicultural and harvesting points of view, many advantages are gained and it is desirable to further promote the use of cable systems. FAO in this respect has carried out a number of international training seminars also, in cooperation with bilateral donors, ILO, ECE and IUFRO.

The simplest system which has been recommended and introduced in various countries is the traditional gravity skyline cable system. The setting up of such a system requires a survey of the skyline corridor and the selection of appropriate supports, which are required for a multispan cable logging setting. Generally, these systems have spans of 1 000 - 1 500 m and logs can be dragged in 25 m from both sides of the skyline and with extended choker cables even further. As setting up time for long distance cable system often takes up to 50 percent of the operating time, it is understandable that a minimum wood quantity per setting will be required. Experience has shown that the minimum volume harvested should be equal to the cable length distance of the setting. Skylines with a carrying capacity of 2.5 tons and a cable length of 1 000 m can easily transport 15- 30 m³ per day, with costs of US$ 10 to 20 per m³.

With more and more plantations reaching the age of silvicultural treatment and harvesting and with the application of more intensive management and harvesting systems, the use of mobile cable machines can be a major progress in future refined and more productive forest operations. The main advantages of mobile short distance systems vis-a-vis the traditional skylines are that they require considerable less setting up time (normally 15-20 percent of operating time is sufficient) and thus lower wood volumes per unit area. The prerequisite, however, is a well established road network system.

Depending on the maximum load a system can carry, one distinguishes between small, medium and heavy duty equipment. Loads normally range from one to four tons, with cable lengths from 300 - 500 m. Mobile cable yarders as attachments to agricultural tractors have proved to be very economical, easy to install and operate. Carrying capacities however are limited to one ton with maximum spans of 300 m. Setting up time will only require 2-6 working hours, depending on the number of intermediate supports. Average hourly productivity may range from 3 to 5 m³, with costs of US$ 5-10 per m³.

## ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Wood industries require a continuous supply of raw material, which however has to be based on sustainable resource utilization, giving priority to long-term needs rather than short-term gains. In many countries, forest-based industrial development has shifted from timber mining operations to diversified forest-based enterprises. This not only is more in line with sustained yield resource management, but allows diversification of activities and increases the level of income of local communities. Stable ecological conditions, particularly on steep terrain, are a most important factor, having a direct influence on yields of agricultural products, preventing soil degradation and enhancing soil fertility. The forest itself with its large reserves of plant and wild animals can provide important supplement to the staple diet of local populations. One concept which has had quite some success was the promotion of agroforestry systems, supporting the planting of multipurpose trees for food, fodder, fuelwood, timber, soil fertility improvement, etc. Considerable prospects were achieved in reducing degradation of land and pressure on scarce farm resources and at the same time establishing new resources to increase availability of raw material for wood-based industries. In line with environmental sustainable resource management more emphasis will need to be placed on refined harvesting practices such as the use of plastic chutes, use of cable systems in combination with environmentally acceptable road construction techniques. Assessment of environmental and social impact of harvesting and road construction activities will be indispensable requirements under modern forest management practices.

## EMPLOYMENT AND TRAINING

In a recent survey carried out by FAO with the support of the Forestry Training Programme of Finland on forest harvesting training needs in 12 African countries it became evident that due to temporary or seasonal work in forest harvesting a high turnover in manpower employment was recognized. This will have a great impact on training needs and facilities. In general, it was observed that forest harvesting at the university level was covered adequately in most of the programmes with a time share of 10-15 percent of the total curriculum. At the technical level, generally, reduced versions of the university curricula are taught. Training at the vocational level was the most needed and a considerable shortage of permanent training facilities was noticed. This is quite evident from Table 4.

Table 4: Survey on harvesting training needs in selected African countries[1]

| | Managers | Technicians Supervisors | Foremen | Workers |
|---|---|---|---|---|
| Estimated employed manpower in raw material procurement for industries (in 1989) | 800 | 2 800 | 7 000 | 90 000 |
| Estimated annual training needs | 320 | 1 060 | 2 100 | 32 000 |
| Educational level | University level | Technical and vocational level | | |
| Number of existing institutions | 15 | 24 | | |

[1] Cameroon, Congo, Côte d'Ivoire, Gabon, Ghana, Kenya, Liberia, Nigeria, Tanzania, Zaire, Zambia, Zimbabwe.

The main aim in strengthening manpower capabilities in forest harvesting is to increase the efficiency of operations, making the best use of the manpower, equipment and raw material based on the sustainability of the resource base and to broaden the social dimension, promoting the development of participatory activities.

## CONCLUSIONS AND RECOMMENDATIONS

Forest harvesting needs to be seen in a broader context, making better use of a wide range of forest products, both wood and non-wood outputs, based on sustainable forest resource management.

Recognizing the importance of stable ecological conditions, particularly on steep terrain, increased efforts are required to further develop environmentally sound mountain forest operations.

Emphasis will have to be placed on appropriate opening up of mountain forests, permitting the introduction of modern forest harvesting systems, raising the level of sustainable production output and decreasing forest harvesting losses.

The transfer of appropriate harvesting technology will be essential to meet environmental and social obligations, utilizing and maintaining mountain forest ecosystems, providing the necessary raw material and supporting agricultural development and thus food security.

In particular, labour-intensive operations should be promoted to provide employment and income and thus direct social benefits from the forests to populations living in and around the forest, advocating an active contribution to support sustainable forest management.

Due to the rapid evolution in forest harvesting techniques, the establishment of more and more plantations in developing countries and the fact that there is still a considerable lack of trained manwpoer, further efforts will be required to strengthen training institutions at all levels and to disseminate information, training and extension material.

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# WORK LOAD AND OUTPUT IN DIFFERENT ACTIVITIES DURING FINAL CUT

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## RESUMEN

El presente estudio resume las experiencias realizadas en una faena de tala rasa, en que se evalúa la carga física y el rendimiento cuando el trabajo se realiza con una configuración 1:4 en bosque y en cancha. La investigación se realizó en una cuadrilla de estudios de abastecimiento de Forestal CELCO Ltda., a la cual se le mejoraron las condiciones de trabajo y de vida en los campamentos. Los resultados muestran que la configuración evaluada lleva a un marcado desequilibrio en la carga física de los trabajadores de bosque y de cancha, siendo significativamente más pesadas las tareas en el bosque. Se analiza la posibilidad de aumentar los rendimientos redistribuyendo los trabajadores o estableciendo un sistema de rotación de funciones.

## 1. INTRODUCTION

It is now more than five years since Forestal CELCO Ltda. started a project to study ergonomic and productive aspects of forest work. The main purpose was to obtain information allowing to protect human resources and to increase labour efficiency. The project, which is being carried out jointly with the Laboratory of Ergonomics of the University of Concepción, has already provided useful information which has been reported in the literature (1)(2)(3)(4). The first step was to select two study crews, one to be specialized in forest management and, the other, in forest production. The selection was made searching for workers representative of Chilean forest labourers (5). For that purpose, anthropometric as well as physiological criteria were used.

After selection, adequate forest camps were built, including bed-room, recreation and dining room and kitchen. The diet, during the present study supplied around 18.337 kJ (4.500 Kcal) daily in five meals. The foods were well balanced in terms of nutrients, specially in those which are insufficient in the diet of these workers. Cooks were trained with special emphasis in hygienic aspects.

In each activity studied the workers received adequate tools as well as safety equipment. Furthermore, some studies had the aim to search for the best work method amongst various alternatives. Special importance has been given to training and, after experiences carried out with the study crews, clear guidelines have been provided for the transference of the technologies adopted, to labourers working for contractors.

The previous description gives a general idea of the context in which this study of final cut is situated. The basic idea was to introduce some variables of the workers to the traditional work studies. In other words, time studies were supported by telemetric follow up of cardiac frequency. Up till now, work load has been seldom evaluated in the Chilean forest workers. In our opinion, cardiac frequency can provide important information to establish weather the output observed during time studies could be reproduced under habitual working conditions. In many cases, standard values for output, obtained from time studies, are higher than those observed under normal working conditions. In such cases the workers, when observed, might adopt higher working rythms than those they could keep to avoid fatigue at the end of the shift.

The present paper summarizes part of the studies which are being carried out during final cut. Output during this productive activity is closely related to human effort because is a team work which includes activities in the forest, namely felling, debranching and winching, and in the lumber yard, specifically, loosening choker to release logs from the tractor, cross-cutting and piling.

The aim was to analyse physical work load and output during final cut when work is performed with 5 workers in the forest and 5 workers in the lumber yard. It was expected to contribute to the search of appropriate technology. In other words, to determine optimal levels of output ( according to the stand, the ground and the environment) without leading the workers to fatigue.

## 2. MATERIAL AND METHODS.

The study was performed in 1989 during the winter season. It has to be explained that the VII Region of the country, where all the evaluations were carried out, has a Mediterranean climate. To illustrate the characteristics of the winter season, table 1 summarizes environmental data.

Table 1

Some characteristics of the physical environment, during the winter, in the area where the study was performed

| Variable | Unit | $\bar{x}$ |
|---|---|---|
| Dry bulb temperature | °C | 9.0 |
| Relative Humidity | % | 82.0 |
| Rainfall | mm per month | 142.2 |
| Air velocity | m/seg | 1.1 |

The study was carried out in a forest plantation of radiata pine. The main characteristics of the stand are summarized in table 2.

Table 2

Characteristics of the stand where the study was performed

| | |
|---|---|
| Year of plantation | 1959 |
| Surface (ha) | 22.8 |
| Density (trees/ha) | 679 |
| DAP (Diameter at chest height;cm) | 31.5 |
| Basal Area (m2/ha) | 50.4 |
| Volume UI = 10 cm (m3sss/ha)* | 526.1 |
| Site index (m)** | 27.0 |

*=utilization index; solid cubic meters under bark per ha
** = height at 20 years

## 2.1. Laboratory studies.

Before starting field experiences, workers were studied in a field laboratory located close to the camp. Physical fitness was evaluated by estimating the aerobic capacity and body composition of each labourer. The method of Durnin and Womersley (6), validated for Chilean populations (7), was used to evaluate body composition in terms of fat and fat free mass content of their bodies. Aerobic capacity was determined with the technique of Maritz et al (8). The efforts were performed on a bicycle ergometer Body Guard 990 (Norway). Oxygen uptake and cardiac frequency were measured in steady state, during each of four exercises, using conventional methods recently described by Apud, Bostrand. Mobbs and Strehlke (9).

## 2.2. Field studies.

Time was continuosly recorded by one observer during each shift evaluated. Activities were classified as principal and secondary. Principal times were considered all those operations strictly related to the main activity. For example, in the case of power saw operators doing felling work principal times were cleaning work area, felling and displacement between trees. Secondary times were, amongst others, tool maintenance, adding fuel to the power saw and so on.

In addition, other observer, did recordings of activities, every second minute, together with cardiac frequency countings. Cardiac frequency was measured using a telemetric unit designed in Chile (Cardiotelemetro, Universidad de Concepción). Three chest electrodes, connected to a small transmitter, send the cardiac sound in FM waves to a receiver. A "personal stereo" was used, from where heart beats were counted. The "30 beats method" (9) was employed, doing the countings in the last half of the corresponding minute.

During the evaluations carried out in the forest and in the log yard, the more relevant characteristics of the trees, the stand and the logs were measured according to the specific activity being evaluated. Although the follow up was individual, and not as a whole team, the daily output for the crew, expressed as cubic meters was recorded daily at the end of the shift.

### 2.3. Organization of work.

As explained before work was organized with five workers in the forest and five in the lumber yard. In the forest one worker did felling of the trees with power-saw, three labourers did debranching with axes and one of them did winching work, meaning to fix the logs to the tractor. Meanwhile, in the lumber yard, one worker did the loosening of the choker to release trees from the tractor, one power-saw operator did cross-cutting and three labourers did piling work.

## 3. RESULTS AND DISCUSSION.

### 3.1. Characteristics of the workers.

In table 3 it is possible to observe the age, body weight, estature, body fat, fat free mass, aerobic capacity and "sustainable load" for ten workers of the permanent crew for studies of production.

Table 3

Physical characteristics of the permanent crew
for studies of production

| VARIABLES | Unit | $\bar{x}$ | DE | Range |
|---|---|---|---|---|
| Age | years | 26.3 | 3.4 | 23-31 |
| Body weight | kg | 60.1 | 7.7 | 50-70 |
| Estature | cm | 164.0 | 6.6 | 159-177 |
| Fat mass | % | 11.9 | 3.4 | 7.1-15.7 |
| Fat free mass | kg | 53.1 | 7.2 | 45.7-65.0 |
| Aerobic capacity | l/min | 3.31 | 0.4 | 2.82-4.13 |
| Aerobic capacity | ml/min/kg | 55.1 | 3.8 | 48.8-58.8 |
| Sustainable load | beats/min | 112 | 3.9 | 106-116 |

The data presented in table 3, reveal that the workers are representative of the average Chilean forest worker. Basically, their estature is low and body weight is proportional to their size. They are slim, as judged by the body fat content. Fat free mass indicates adequate physique in terms of muscle and skeletal development. Aerobic capacity reveals good physical fitness. It is important to highlight these results, because, in our opinion, studies of this nature should be carried out in samples of labourers not different to the working population, specially if conclusions might be used to develop standards, work methods, tools or others which later will be generalize to the entire population.

In table 3, it is also included what we have called "sustainable load". It is convenient to keep this figure in mind because it should be avoided to exceed this limit of cardiac frequency, as average, during a normal shift of approximately 8 hours. The idea on behalf is that after heavy activities, which might increase cardiac frequency to higher levels, enough rest pauses should be provided and they should be organized in such a way that, at the end of the shift, the average cardiac frequency should not exceed, approximately, 112 beats per minute. As it was shown in table 3, this is not a rigid value, because it is calculated taking into account the age of the subjects and also the difference between resting and maximal cardiac frequency (9).

### 3.2. Production.

Table 4 summarizes the production of the study crew during the winter season when this study was carried out.

Table 4

Production of the study crew

| Working time | Production | | % Sawn Wood | number of |
|---|---|---|---|---|
| Hours | m3 | m3/man/hour | | days |
| 6.64 | 94.7 | 1.43 | 75.6 | 70 |
| 7.75 | 110.0 | 1.41 | 74.7 | 50 |
| 8.07 | 115.0 | 1.42 | 74.2 | 40 |
| 8.67 | 127.4 | 1.47 | 74.1 | 22 |

As it is shown in table 4, total production increased in proportion to working time. However, it is also important to notice that average production per man/hour is fairly constant. As it will be discussed in more detail, this seems to be related to the organization of work and, specially, to the physical work load in some tasks performed in the forest.

### 3.3.Physical work load and times during work performed in the forest and in the log yard.

In table 5 are included times per activity and average cardiac frequency for each of them. To make it simpler, times have been divided into principal, secondary and waits. As it can be observed in table 5, the organization of work, with five workers in the forest and also five persons in the log yard, leads to a noticeable unbalance in the physical work loads of labourers as judged by differences in heart rate . All activities in the forest, specially debranching and winching , are heavier than the activities performed in the log yard. Average cardiac frequency for complete shifts was 114.8 beats per minute for debranching and 115.3 beats per minute for winching.

As pointed out before, the average sustainable load was 112 beats per minute, within a range of 106 and 116 beats per minute. This reflects that debranching with axe and winching were performed very close to the limit of sustainable work load. There is no doubt that principal activities during debranching and winching, which occupied 53.1 and 52.4 percent of the total work time respectively, are heavy. As it can be observed in table 5, the average cardiac frequency was 133 for debranching and 130 for winching. This can be taken as indication that waitings are completely justified. Although no discrimination was made to detect if waitings were due to delays from previous stages of work or if they were rest pauses, it would be practically impossible to reduce this time to increase debranching or winching times. As pointed out before, cardiac frequency for the shift, including waitings, was within the higher allowable limits to avoid fatigue at the end of the work day. Therefore, these two activities performed in the forest are the "bottle neck" if aiming to increase output. There are some alternatives and one of them would be to reduce the number of workers doing piling to two and increase the number of workers debranching to four. This will allow to increase debranching work in about 25% if the workers keep the rythm that they sustained during

## Table 5

Average time per activity (%T) and mean cardiac frequency (fC) in beats per minute during work evaluated in the forest and in the log yard

| Activities | Work in the forest* | | | | | |
|---|---|---|---|---|---|---|
| | Felling<br>n=8 | | Debranching<br>n=7 | | Winching<br>n=2 | |
| | %T | fC | %T | fC | %T | fC |
| Principal | 36.6 | 117.9 | 53.0 | 133.0 | 52.4 | 130.2 |
| Secondary | 30.4 | 95.1 | 12.0 | 93.0 | 9.6 | 104.6 |
| Waiting | 33.0 | 84.1 | 35.0 | 87.7 | 38.0 | 99.5 |
| All | 100.0 | 102.6 | 100.0 | 114.8 | 100.0 | 115.3 |

| | Work in the log yard | | | | | |
|---|---|---|---|---|---|---|
| | Cross-Cutting<br>n=9 | | Piling<br>n=7 | | Loosening choker<br>n=2 | |
| | %T | fC | %T | fC | %T | fC |
| Principal | 46.9 | 108.7 | 26.7 | 122.6 | 34.4 | 118.1 |
| Secondary | 25.2 | 88.3 | 11.9 | 94.9 | 10.6 | 96.9 |
| Waitings | 27.9 | 79.8 | 61.4 | 81.6 | 55.0 | 77.3 |
| All | 100.0 | 97.0 | 100.0 | 96.9 | 100.0 | 92.1 |

n= number of complete shifts studied per activity

* to make comparable the information obtained in forest and log yard, the same power saw operators were measured felling and cross-cutting. The same workers did debranching and piling and one worker did winching and loosening choker.

the present study. In such a case, work load of felling, winching, loosening chokers, cross-cutting and piling work will increase. If this is analysed, based on the average cardiac frequency (table 5), it seems possible, except for winching which might become unduly heavy. Consequently, if the number of axe workers is increased it will also be necessary to include another worker to help binding logs to the tractor (winching). However, there is another problem that needs some comments. Although workers doing piles used only 26.7 percent of their working time in the principal activity, if one of them is removed to make him work debranching, piling time will increase for the two workers left doing this job. This, seems possible because of the low average cardiac frequency but there will be more manual movement of wood to make the piles increasing the risks of muscles and joints damage. There is evidence in the country (10) that piling is associated with high complains of low back symptoms.

For these reasons, it seems wise to analyse other alternatives. One of them, would be to consider job rotation. This could be done at mid morning, lunch time and mid afternoon. In such a case, power saw operators could do half time felling and the other half cross-cutting, the same would be possible for debranching and piling work and also for winching and loosening the choker. The greatest advantage is that work load would be more balanced, the risky piling work, which has a high component of static muscular effort, would be reduced to half time because of the combination with debranching work, which is mainly dynamic, and the wincher will be also favoured doing half time the opposite work (loosening the choker) which is much lighter activity. It is also likely that job rotation may result in higher output, because of the better distribution of the work load. However, this or any other alternative have to be evaluated before arriving to definitive conclusions. As a matter of fact, we are just finishing the studies of job rotation. Although the information on work load and output is being processed, from the point of view of workers, the alternative has been welcome. Their opinion is that work load is better shared.

Finally, we are certain that there are other alternatives to increase output and reducing work load by increasing mechanization. At present one Scandinavian system has been incorporated by some enterprises in such a way that debranching is done with power-saw. However, there are a number of considerations before such system can be recommended. One of the main objections is that work load when using power-saws is directly related to body size and body composition (unpublished data). As it was shown, a Chilean worker with 1.64 m height and 60 kg body weight can not be compaired to Scandinavian labourers. Amongst other considerations, the problem is that not only power saws are needed. Manual winching, loosening the choker and piling can be increased to very dangerous levels and, therefore, they would also need to be mechanized. Although the expected growth of forest work, due to new wood related industries which are being installed, will increase the demand of labourers, the question is: under prevailing circumstances, would small contractor's firms working for large companies be able to pay the cost of mechanization ?. In general terms, it is possible to speculate that both alternatives will coexist and in both cases work physiological methods, combined with work study techniques, might provide valuable information to protect workers of heavy manual work as well as to optimize quality and quantity of work, aspects which are amongst the aims of Ergonomics.

## 4. CONCLUSIONS AND RECOMMENDATIONS

The discussion of the results included the most important conclusions which can be summarized as follows:

4.1. The study was performed in a group of workers representative of the average Chilean forest worker. The only difference, in connection to other labourers, was improved living conditions in the forest camp as well as better training, safety equipement and tools maintenance.

4.2. Final cut organized with five workers in the forest and five in the log yard showed a marked unbalance, the work load being heavier in the forest.

4.3. Debranching and winching work is performed at the highest average cardiac frequency recommended for an eight hours shift.

4.4. It is suggested that output could be increased by doing a redistribution of workers or by job rotation. Both alternatives are at present being studied.

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# A MODERN APPROACH TO THE DESIGN OF ERGONOMICALLY SAFE CONTROL SYSTEMS FOR FOREST MACHINERY

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## SUMMARY

Considered is a method, based on simulation modeling and intended for design ergonomically safe systems of control units for knuckle-boom forest machines. Two practical problems have been attempted: optimizing the make-up of control units designated purpose of the control, its stand-alone and way of manipulation - push; pull; right; left; etc., to effect each controllable movement of the mount-on equipment) with the result that the maximum efficiency for the given operational environment is achieved; optimization of cab arrangement to achieve ergonomically optimal operator's working posture.

The underlying principles for the models allow these methods to be used at the stage of design.

Keywords: Knuckle-boom forest machine, simulation modeling, design of ergonomically safe control systems, man-machine system

## INTRODUCTION

Knuckle-boom equipped machines appear to be a reference direction for technological advancement in forest operations. Control of these machines is, as a rule, effected from operator's cab. This work is, nevertheless, considered medium heavy due to a great number of control functions to be performed (from $5 \cdot 10^3$ to $10 \cdot 10^3$ ons and offs per shift) and considerable effort to be exerted. High intensity of work results in operator slowing down in tempo in 3 to 4 hours time, thus affecting machine efficiency. In view of the ever-increasing number of such machines being operated in the forestry sector, the losses incurred only due to inadequancies in the design stage of man-machine system, may easily be estimated.

Let us consider two practical problems aimed at enhancing engineering capabilities of the machine by way of improving on operator-controls interaction. The first is optimizing the make-up of control units, i.e., the designated purpose of the control, its stand-alone and way of manipulation (push; pull; right; left; etc.) to effect controllable movements of the mount-on equipment at which the man-machine system attains its maximum efficiency. The second is an optimum design of controls arrangement within the cab to achieve ergonomically best operator's posture. Both the problems may be tackled proceeding from the construction of corresponding mathematical models thus allowing for mathematical methods to be used at the design stage.

## MAKE-UP OF CONTROL UNITS

The functioning of knuckle-boom machine is composed of a series of operational actions, the role of each, for the given type of machine, specified by the designer. The operator's work in controlling the process and, consequently, the information exchange within the man-machine system follows a definite algorithm. The operational process thus represents a sequence of randomly entering individual jobs to be responded to by the operator.

Breaking down the process of control into individual jobs is based on the notion that each executive response is a result of processing information which precedes the act of response. In order to construct the model accounting for the effect of the make-up of control units on machine efficiency, the time for executing each job is divided, after (V.I.Nikolaev, 1973), into seven consecutive stages: signal detection ($t_{i1}$); their differentiation (sorting out) ($t_{i2}$); estimating the message conveyed ($t_{i3}$); situation assessement and decision taken on the job emerging ($t_{i4}$); shaping the result in the form sensible for execution ($t_{i5}$); search for means to execute the command ($t_{i6}$); execution of control function ($t_{i7}$).

Consequently, duration of the cycle responsible for machine efficiency is determined as a sum

$$T_c = \sum_{i=1}^{n} \sum_{j=1}^{7} t_{ij} , \qquad (1)$$

where $n$ - the number of jobs over the cycle.

The effect of controls make-up is represented by quantities $t_6 - t_7$. To establish the respective analytical expressions let us follow up the operator's work when executing an arbitrarily chosen job.

The fifth stage - the decision making is the process of visualising the decision in terms of output signals. Here the operator is formulating the command data, which may be expressed as individual data supplied by data reducers used, i.e.

$$\dot{I}_5 = - \sum_{l_k} \log_2 p_{l_k} , \qquad (2)$$

where $p_{l_k}$ - probability for the formation of the signal (summing is done after the control units used for executing the job).

Time for the stage being

$$t_5 = \tau_0 \, (1 + 0.03 a \dot{I}_5) \cdot \dot{I}_5 \, . \qquad (3)$$

The sixth stage - search for means to execute the command is determined following the individual data of the data reducers used

$$\dot{I}'_6 = - \sum p_{m,\ell_k} \cdot \log_2 p_m \, , \qquad (4)$$

where $p_m$ - probability for the particular control unit $m$ to be used; $p_{m,\ell_k}$ probability for signal $\ell_k$ formation by machine unit $m$.

The search for means to execute the command is influenced by reducer data sum, indicative of the intricacy for the choice of control and equal to mean entropy, i.e.

$$H'_6 = \sum_{m=1}^{M} p_m \log_2 p_m + \sum_{u=1}^{\vartheta_M} p(u) \log_2 p(u) \, , \qquad (5)$$

where $p(u)$ - probability for applying the $u$-th type of manipulation (push; pull; etc.); $\vartheta_M$ - numbers of diverse manipulations; $M$ - total number of control units.

The time for search depends also on individual entropy of monotype manipulations

$$H''_6 = \sum_{C} \log_2 p(\vartheta) \, , \qquad (6)$$

where $C$ - plurality of manipulation types used by the operator to execute the job; $p(\vartheta)$ - probability for manipulation type to be included in group $C$.

Accounting for entropy of manipulation types is related to the nature of operator's work while executing control operations. Man's central nervous system, for a definite type of the movement of his body to be effected, undergoes, accordingly, a pre-start period resulting in time delay, whose duration depends on the diversity of movements involved as well as on the peculiarities of operator's nervous system. The science of human engineering provides for detailed quantitative analyses of the said dependence and substantiates the given phenomenon.

Prior to acting, the operator is to identify, either visually or palpatedly, the respective control unit. The time for identifying

$$\tau = \tau_0 M_0 \, , \quad \tau = \tau_T M_0 \, , \qquad (7)$$

where $M_0$ - number of control units to be used to execute the job; $\tau_T$ - time for palpably perceiving a separate control unit.

As it follows from the above deductions, the operator's time at the given stage

$$t_6 = \tau_0 (1 + 0{,}03 a \dot{I}_6) \dot{I}_6 + \tau \, , \qquad (8)$$

where

$$\dot{I}_6 = \dot{I}'_6 - H'_6 - H''_6 ,$$
$$a = bit^{-1}. \qquad (9)$$

The seventh stage - the execution of control function, is the process of coding the commands in terms of the respective data reducers. Time $t_7$ for this stage is made up of two components, the first of which $t'_7$ is the time to overcome the "movement automatism" set in, and depends on the number of movement types the operator has to perform. Time needed to change over from $r$ type of movements to $r+1$ type is designated as $\tau_{r,r+1}$.

Assuming that $\tau_{r,r+1}$ is equal for all $r$ , the time to be sought is expressed as

$$t'_7 = -\sum_{C} (1 - p(\vartheta)) \cdot \frac{1}{1 - \vartheta_M} \sum_{r=1}^{R} \tau_{r,r+1} , \qquad (10)$$

where $C$ and $R$ plurality of the movement types used and the number of changeovers therein, respectively.

The second component $t''_7$ depends upon the technical features of control units (turn-on time) and may, in principle, be determined after the expression

$$t''_7 = \max \{ \tau_{m_1, m_2} ; \tau_{u_1, u_2} \} \qquad (11)$$

Thus, a mathematical model accounting for the effect of the make-up of control units on the duration of the operational cycle (1) has been constructed.

The related computer software support is so designed that it be necessary to enter but the initial variant for the make-up by way of filling in on the display specialized tables and a cyclogram. The program automatically reshopes the data in the rightmost parts (2) - (10). Introducing several constraints is also possible.

A make-up, optimal after criterion (1) and five approximated variants with their duration respectively established (1) are thus being obtained.

## CAB ARRANGEMENT

Optimum make-up of controls established, we may pass over to the other problem - optimum design of the control units proper and their layout within the cab. Here, the best solution is provide for operator's optimum working posture, while the quota of working time spent in the optimum posture, when performing the given control algorithm, will serve as a criterion for efficiency.

Human body mechanics, when engaged on a specific purpose, rather than data-based approach, has here been used to construct the corresponding mathematical model.

Let us introduce a system of coordinates referred to the operator's seat. Then, each control unit may be described by the following parameters:

- coordinates for a fixed point (point of support);
- pair of angles defining the type of movement for each boundary condition and the deflection number as time function vs neutral position;
- distance between the fixed point and the point arms (feet) are positioned.

This coordinate system may be apprppriated to define practically any control units used with both lever-pedal and semiautomated control knuckle-boom machines.

The operator's body in human body mechanics is treated as a mechanical system. That is why the model for the operator is considered as a solid body with three-member bodies attached, and kinematics equations for each are derived proceeding from the control algorithm to be effected. Angles for member-body orientation in the given plane and the angle for orienting the very plane of the three-member body are used as generalized coordinates. These variables have been chosen, as the physiology of labour is known to have established optimum boundaries for these angles, actually defining operator's working posture. The related analytical expressions are presented in detail in (V.N.Oblivin, I.A.Sokolov, A.M.Leitass, 1988). Anthropometric data are, as initial data, also used in these equations.

The present method is computer-practiced in conversational mode. This allows for diverse design alternatives to be immediately assessed and checked on. The degree of optimum of the operator's posture may readily be checked vs the control system chosen. In case of no optimum agreement the designer enters in the corresponding tables the adjusted values for the respective parameters.

The designer is at liberty to set communications between the regimes of the system and choose different design procedures. The optimization however, is to be effected as follows:

- establish the coordinates for points of support of control units;
- establish their geometrical configuration;
- establish the orientation angles;
- establish the angle vs neutral position.

## CONCLUSIONS

The solution of the above problems is based on simulation modeling of operator's activities within the system of control. Such an approach allows for these methods to be used not only for ergonomical assessement of machines developed, but also for the same already at the design stage.

Check of the method by way of juxtaposing estimated efficiency figures and controls parameters for two machines with the same operational cycle and operated in comparable environments has shown a fairly good agreement with the experimental values. Thus, the models proposed adequately describe the system to be studied and the optimization method itself may be used for design estimates when working on novel machinery.

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# BELASTUNG DER WALDARBEITER MIT LÄRM UND SCHWINGUNGEN

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## SUMMARY

In many countries, where technical development of forestry working machines has not reached the full mechanization step yet, there are machines ergonomically unsuitable to the worker. That´s why his charges with noise and vibration are high. Without using any hearing protection, noise is dangerous for health. There is necessary to shorten the working time, some working methods or some meachines have to be dropped because of vibration.

Keywords: workload, forest workers, noise, vibration.

## EINLEITUNG

Die mechanische Arbeitsmittel, die vor einigen Jahren in manchen Entwicklungsländern die Handarbeit bei der Holzernte ersetzt haben, brachten neue Belastungen der Waldarbeiter mit. Die Arbeitsmittel der Teilmechanisierug der Waldarbeit sind noch nicht nach ergonomischen Kriterien, die für die hochmechanisierte Holzernte gelten,gebaut. Darum verursachen die Arbeitstechnologie und die Maschinen in heutiger Stufe der technischen Entwicklung noch immer hohe Arbeiterbelastungen mit dem Lärm und den Schwingungen. Die Einführung der leistungsfähigeren, stärkeren Maschinen, der Arbeitsweise ohne Zeitverluste und ohne Handarbeit kann diese Belastungen, die auch die Gesundheit gefährden, sogar vergrössern.

## UNTERSUCHUNSMETHODEN

Die Belastungen der Arbeiter sind von den physikalischen Grössen des schädlichen Einflusses und von der Dauer der Aussetzung der Arbeiter abhängig. In unseren Untersuchungen, die meistens aus slowenischer (NW Jugoslawiens) Waldwirtschaft stammen, wurden also die Pegel und die Zeit gemessen. Dir Lärmbelastungen wurden aus ganztägigen Lärmpegelmessungen am Ohr der Arbeiter mittels eqvivalenten Lärmpegels ausgedrückt. Der Lärmpegel wurde jede zehnte Sekunde aufgenommen und dann für jedes Arbeitselement als Mittelungspegel ($L_{eqv}$) gerechnet. Mit der Hilfe der Zeitstruktur der Arbeitselemente wurde die Lärmbelastung ($L_{eqv}$) für die Ganze Arbeitszeit errechnet. Die Zeitanteile verschiedener Lärmpegelgruppen (2,5 dBA breit) oder die Häufigkeitsverteilung des Lärmpegels in der Arbeitszeit, verglichen mit den ISO Grenzen für kürzere Aussetzungsdauer, wurde zum Beurteilen der Überlastung der Arbeiter genommen.

Bei den Schwingungen wurden die Beschleunigungen an den Griffen oder am Sitz während des Hauptarbeitselements nach Terzbänden der niedrigen Frequenzen gemessen. Diese Frequenzverteilungen wurden mit ISO Grenzen für verschiedene Aussetzungsdauer und Aussetzungsweise verglichen. Daraus kann man schliessen, wie lange solche Belastungen oder reine Arbeitszeit täglich dauern dürfen. Wenn die tägliche Arbeitszeitdauer in bestimmten Arbeitsverhältnissen länger ist, dann sind die Arbeiter überlastet. Um die Arbeitselemente oder die Arbeitsmittel miteinander zu vergleichen, wurden auch die linear gemessene Beschleunigungen während der ganzen Tagesarbeitszeit gebraucht.

## MOTORMANUELE ARBEIT MIT DER MOTORSÄGE

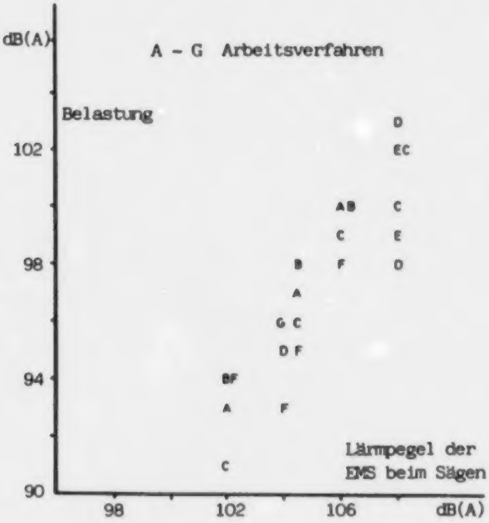
Die Belastung der Arbeiter mit dem Lärm ist stark von dem verwendeten Typ der Motorsäge abhängig. Man kann eine ziemlich lose aber beweisbare Abhängigkeit der Lärmbelastung der Arbeiter während der ganzen Arbeitszeit von dem Lärmpegel der Motorsäge im Trennschnitt beim Testen beobachten (Graph 1).

Die gleiche Motorsäge kann aber die Belastungen ($L_{eqv}$) verursachen, die sich untereinander bis zu 3 dB(A) unterscheiden, es kann also zu einer Verdoppelung der Belastung kommen. Die Unterschiede entstehen wegen verschiedener Arbeitsverfahren, wegen verschiedener Arbeitsverhältnissen und auch wegen verschiedener Arbeitsweise der einzelnen Arbeiter. Dabei verursachen die neueren Arbeitsverfahren (z.B. Langholz ohne Entrinden oder Kranlängen ohne Schichtholz) und die Arbeit im Schwachholz höhere Lärmbelastungen.

Bei einer Untersuchung in der BRD in den siebziger Jahren (Lipoglavšek, 1976) wurden Belastungen zwischen 91 und 103 dB(A) festgestellt. Die Arbeitsverfahren, bei denen Bombosch (1988) in den Schwachhölzer den Lärmpegel gemessen hat, verursachen Belastungen der Arbeiter zwischen 97 und 102 dB(A), also höhere Belastungen trotz verbesserten Motorsägen. Gute Schnittleistung kann ähnlich als der verminderte Lärmpegel der Motorsäge die Belastungen der Waldarbeiter senken, weil die Zeit der Aussetzung kürzer sein wird.

Die Belastungen der Waldarbeiter mit den Schwingungen an den Griffen der Motorsäge wurden nicht gemessen. Aus den Messungen der Beschleu-

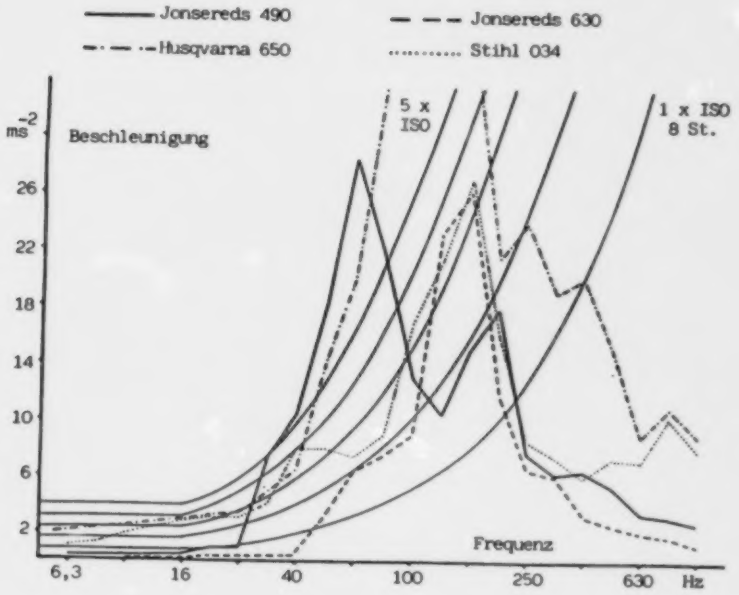
Graph 1 TÄGLICHE LÄRMBELASTUNG DER MOTORSÄGENFÜHRER



nigungen an beiden Griffen in drei Richtungen während der Prüfungen der EMS in Laborverhältnissen kann man aber die Belastungen der Arbeiter bei Fällarbeit schätzen. Beim Sägen (Trennschnitt) übersteigen die Schwingungen an den besten, mit AV-Griffen ausgerüsteten, Motorsägen die erlaubten ISO - Grenzen für 8 Stunden drei- bis viermal. Die älteren Typen der Motorsägen, die teilweise noch immer im Gebrauch sind, übersteigen alle erlaubten Grenzen (fünf und mehrmal).

Graphikon 2 zeigt Frequenzverteilung der Schwingungen an hinterem Griff in vertikaler Richtung von einigen Motorsägentypen. Meistens sind nämlich diese Schwingungen die höchstgemessenen Werte und darum für die Belastung der Arbeiter entscheidend. Um die Überlastungen und Gesundheitsschäden zu vermeiden dürfen die Arbeiter mit den besten, gut unterhaltenen Motorsägen nicht mehr als 1 - 2 Stunden (pro Tag) mit regelmässigen zahlreichen Unterbrechungen effektiv arbeiten (sägen). Bei allen Arbeitsverfahren, wo diese Zeit länger ist, sind die Arbeiter mit Schwingungen überlastet. Man muss also die Arbeitszeit begrenzen bzw. die Normen auf diese verkürzte Effektivzeit berechnen.

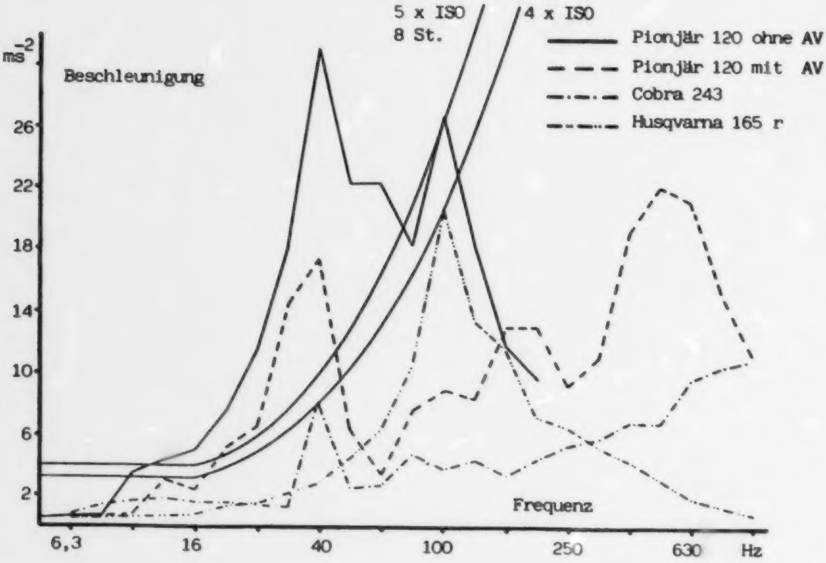
Graph 2 SCHWINGUNGEN AM HINTEREN GRIFF DER MOTORSÄGEN



## ARBEIT MIT FREISCHNEIDGERÄTEN

Bei der Arbeit mit den Freischneidgeräten tretten auch die Belastungen der Arbeiter mit Lärm und Schwingungen auf. Die Antriebsmaschine wird während der Arbeit ziemlich nahe dem Ohr des Arbeiters getragen. Bei einem Versuch mit dem Gerät Husqvarna 165 r schwankte der Lärmpegel sehr unregelmässig zwischen 68 und 108 dB(A). Besonders ungünstig für die Belastung der Arbeiter sind hohe hochfrequente Lärmpegel, die beim Sägen mit der Kreissäge entstehen. Die Lärmbelastung der Arbeiter ($L_{eqv}$) betrug in der Betriebszeit zwischen 94 und 99 dB(A) oder durchschnittlich 98 dB(A), umgerechnet auf die ganze Arbeitszeit (mit 5 Stunden Betriebszeit) 96 dB(A). Diese Lärmbelastungen liegen ähnlich hoch als bei der Motorsägenarbeit. Die Belastungen der Arbeiter mit Schwingungen wurden während der reinen Arbeitszeit (Betriebszeit ) gemessen. Die grössten Beschleunigungen treten an rechtem Handgriff, den der Arbeiter auch ständig in der Hand hat, und in der horizontaler Richtung auf. Die Frequenzanalyse dieser Schwingungen zeigt, dass sie viermal stärker sind als die erlaubte ISO-Grenze für 4-8 Stunden (Graph. 3). Die Arbeiterbelastungen sind wieder gleich den Belastungen bei der Arbeit mit den neuen Motorsägen mit AV-Griffen, wenn auch die Arbeitsdauer gleich ist (1 - 2 Stunden). Das ist aber schwer zu vermuten, weil der Arbeiter hier die ganze Arbeitszeit nur schneidet und keine andere Handarbeit auszuüben hat.

Graph 3 SCHWINGUNGEN DER BOHRHÄMMERN UND DES FREISCHNEIDGERÄTES



## BOHREN DER SPRINGSLÖCHER BEIM RÜCKEGASSENBAU

Mit Otto Motoren getriebene Bohrhämmer, die man auch im Bauwesen verwendet, sind beim Rückegassenbau besonders im Karstgebiet unvermeidbar. Sie stellen aber sehr hohe Belastungen der Arbeiter mit dem Lärm und mit den Schwingungen dar. Der höchste Lärmpegel am Ohr des Arbeiters tritt während des reinen Bohrens auf. Die Spitzen reichen bis zu 113 dB(A), der eqvivalente

Lärmpegel beträgt, abhängig von Arbeitsplätzen, zwischen 102 ind 105 dB(A). Andere Arbeitselemente sind nicht so lärmend aber trotzdem liegt der mittlere Lärmpegel der reinen Arbeitszeit zwischen 102 und 104 dB(A). Die Lärmbelastung der Arbeiter, die bei dieser Arbeit viele Erholungspausen haben ist auch davon abhängig wie hoch der Lärmpegel in den Pausen liegt. Wenn während der Pausen andere Maschinen in der Nähe arbeiten, ist die Belastung in gesammter Arbeitszeit 100 - 103 db(A), wenn die Pausen relativ ruhig sind 99 - 102 dB(A). Dabei wurde gerechnet, dass die Lärmpausen und andere Arbeiten ungefähr 50% der Arbeitszeit dauern. Die Arbeiter sind trotz vielen Arbeitsunterbrechungen an allen Arbeitsplätzen 35 bis 40 % der Arbeitszeit mit dem Lärm überlastet.

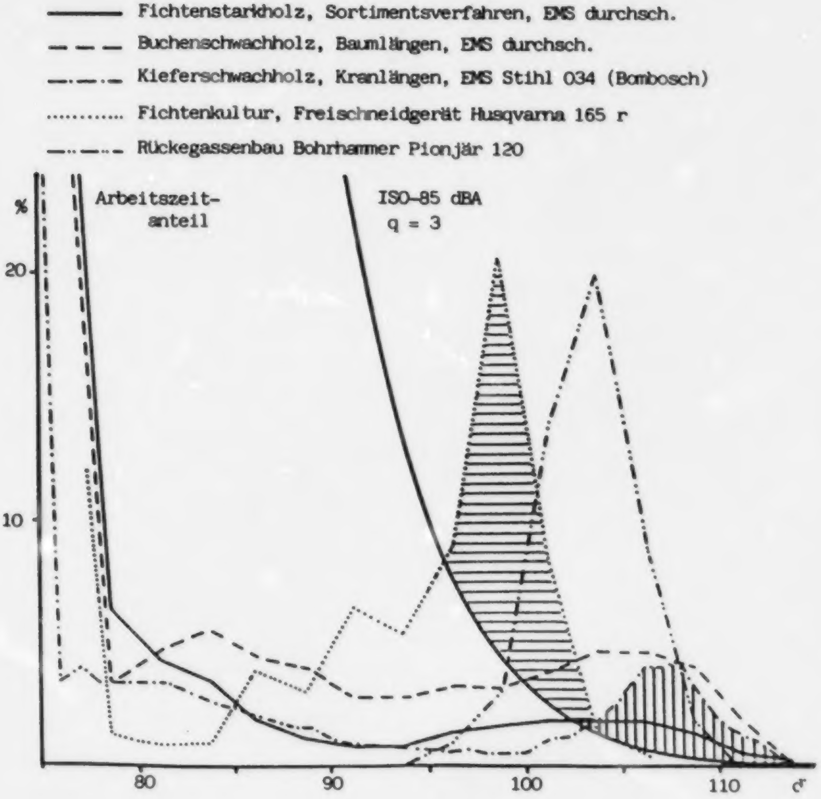
Noch schlimmer sind die Belastungen mit Schwingungen. Die Untersuchungen der Bohrhämmer Pionjär 120 zeigen, dass auch die Schwingungen an sogenannten AV-Griffen während des Bohrens alle erlaubten Grenzen überschreiten. Sie sind entsprechend niedriger von den Beschleunigungen an starren Griffen, aber sie gefährden noch immer die Gesundheit der Arbeiter. Sie überschreiten nämlich die erlaubten ISO Grenzen für 8 Stunden mehr als fünfmal (Graph 3). Nur kleinere leistungsschwächere Bohrhämmer, die aber die Arbeiter abgelehnt haben, verursachen kleinere für die Gesundheit unschädliche Schwingungen, wenn man den Daten des Herstellers glauben darf.

Bei den pneumatischen Bohrhämmern, die bei dem Waldstrassenbau verwendet werden, sind die Arbeiter auch ähnlich überlastet.

Wenn man alle motorgetriebene Handgeräte, die in der Forstwirtschaft verwendet werden, vergleicht, sieht man, dass bei allen Arbeiten die Arbeiter mit dem Lärm und den Schwingungen überlastet sind. Zur Zeit sind auch keine Verbesserungen in Sicht. Die Lärmpegelverteilungen, verglichen mit der ISO-Grenze für kürzere Zeitabschnitte (Graph. 4) zeigen uns, dass die Arbeiter mehr oder weniger immer überlastet sind.

Bei den Motorsägen liegt die Überlastung bei den höchsten Lärmpegel, bei den Freischneidgeräten und Bohrhämmern sind die Lärmpegel etwa niedriger, sind aber ihre Zeitanteile viel grösser. Mit dem Gehörschutz müsste man die tatsächlige Lärmpegel im Ohr wenigstens umd 10, bei den Bohrhämmern um 15 dB(A), senken um die Gehörschäden zu vermeiden. Die Schwingungen sind bei alten Motorsägen und bei den Bohrhämmern so stark, dass man ihre Verwendung nicht mehr dulden kann, bei den neuen Motorsägen und bei den Freischneidgeräten muss man aber die tägliche Aussetzungszeit der Arbeiter verkürzen. Ihre Leistungsfähigkeiten dürfen wegen der schädlichen Einflüssen der Arbeitsmittel nicht voll ausgenutzt werden. Auch die persönlichen Schutzmittel (z.B. die Handschuhe) sind gegen Schwingungseinflüsse nicht genügend wirksam.

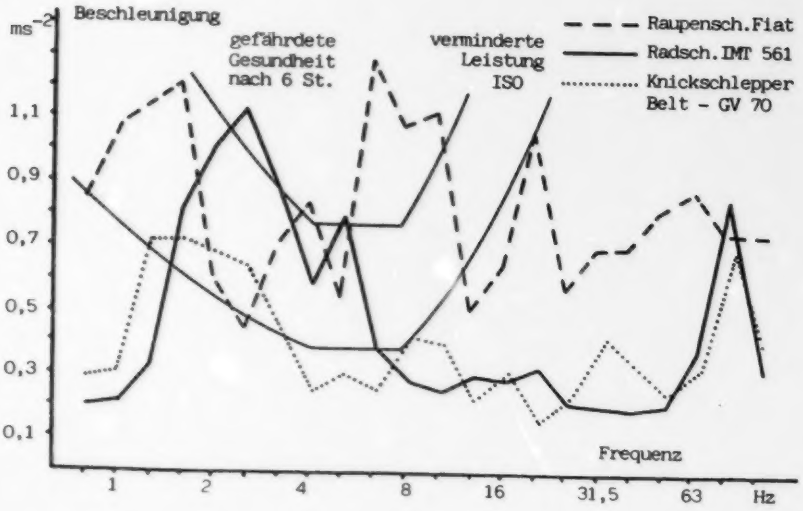
Graph 4 ÜBERBELASTUNG DER ARBEITER MIT DEM LÄRM



## HOLZTRANSPORT

Über Belastungen der Arbeiter beim Holzrücken und beim LKW Transport wurde schon vorher (Ljubljana 1986, Brno 1988) ausführlich berichtet. Beim Holzrücken mit den adaptierten landwirtschaftlichen Schleppern liegt die Lärmbelastung der Fahrer zwischen 89 und 93 dB(A). Beim Rücken mit den forstlichen Knickschleppern steigt sie bis zum 97 dB(A) hinauf. Die Verwendung von etwas grösseren und stärkeren Rad- und Raupenschleppern vergrössert die Lärmbelastungen, ebenso die Verwendung ungenügend lärmisolierter, nur teilweise gesperrter Kabinen. Nur bei den Knickschleppern verwendet man jetzt leichtere Maschinen als früher und darum sinkt auch die Lärmbelastung. Die Schwingungen am Sitz der adaptierten landwirtschaftlichen Schlepper hatten früher nur die 6-Stunden ISO-Grenze verminderter Leistung überstiegen, an jetzt verwendeten etwas stärkeren Schleppern steigen sie über die 6-Stunden Grenze gefährderter Gesundheit über. Nur bei den Knickschleppern sind auch Schwingungsbelastungen wieder kleiner geworden (Graph. 5).

Graph. 5 VERTIKALE SCHWINGUNGEN AM SITZ DER SCHLEPPER



Beim Holzrücken mit den Seilkränen ist die technische Entwicklung auch ergonomisch günstig. Die Lärmbelastungen der Maschinenführer der klasischen Seilkränen betrugen 99 bis 102 db(A), sind aber bei den heute meist verwendeten Mastseilkränen an kurzen Entfernungen bergauf auf 88 bis 89 dB(A) gesunken. Die Schwingungsbelastungen sind bei dieser Arbeit unbedeutend.

Die Lastkraftwagenfahrer bei der Holzabfuhr sind bei dieser vorwiegend psychischen Arbeit auch mit dem Lärm überlastet ($L_{eqv}$ von 77 bis 84 dB(A)). Die Schwingungen verminderen ihre Leistung an etwa mehr als der Hälfte der Arbeitsplätzen. Diese Belastungen gefährden aber nicht ihre Gesundheit.

## SCHLÜSSE

Die Untersuchungen zeigen also, dass in unserem aber auch in vielen anderen Ländern wegen langsamerer technsichen Entwicklung fast alle Arbeiter in der Forstwirtschaft mit dem Lärm und mit den Schwingungen überlastet sind. Nur die Einfuhr oder die Herstellung eigener, ergonomisch dem Menschen angepasster Maschinen kann die Arbeiterbelastung und die Gesundheitsgefahr vermindern.

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# OCCUPATIONAL HYGIENE OF WOOD PROTECTION AGENTS
# RECENT DEVELOPMENTS IN FINLAND

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## SUMMARY

In Finland, the wood protection agents, formaldehyde, and cancer risk are topics of great current interest in the field of chemical hygiene. At the moment, the situation of the antiblueing agents is especially interesting. The chlorophenol product KY 5, which held almost a monopoly for many years, was banned in 1988 because either chlorophenols or their impurities were suspected to be carcinogenic. Now, nine antiblueing agents are accepted officially. Only two of them are in general use:

- Kemtox S 10: (thiocyanomethyl)thiobenzothiazol (TCMTB) + 2-n-octyl-4-isothiazoline-3-one
- Sinesto B: trimethylcocoammonium chloride + sodium-2-ethyl hexanate (2-EHA)

There is only little experience of the use of these substances which replace chlorophenol, and their long-term effects are not sufficiently known. Their acute toxicity is lower than that of chlorophenols. The worker can be exposed to the antiblueing agents at many work stages, from preparation of the solution to handling of the finished boards. It was found that in the use of chlorophenol products, the main exposure took place through the skin.

A biological monitoring method was developed in 1989 for 2-EHA at the Institute of Occupational Health (regional institute of Kuopio). Contrary to chlorophenols, exposure to 2-EHA takes place mainly through the lungs.

Keywords: Sawmills, antiblueing agents, exposure monitoring

# NEW ERGONOMIC PROBLEMS IN MECHANIZED LOGGING OPERATIONS

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## SUMMARY

A "Health Risk Program" for forest work has been developed in Sweden in order to improve health risk identification by systematic evaluation of the relations between work and health complaints, and to create a base for decisions on different actions to reduce the health risk. This paper deals particularly with logging-machine operators and the problem of the "overload syndrome", characterized by complaints and injuries to the neck, arms and cervical spine. The results of health investigations of 1,174 machine operators indicate a prevailing average overload syndrome of 50%, mainly due to one-sided, repetive, short-cycle working movements with arms and hands.

The analyses show that a whole battery of measures is needed to radically improve this serious situation. Single measures might be positive, but are not enough. To be effective, the full program of measures must be carried out, and be adapted individually to each machine operator. Improved technology/ergonomics is needed, especially regarding the sitting working posture in the cabin, i.e. design of the arms of the chair, controls, and instruments. Important individual factors are working techniques, micropauses, and physical fitness. New work organization is the most difficult part of the measures to realize in practice, but has also the highest potential for improving the situation. Examples of issues to address are design and length of the working shift, job rotation, work tasks and responsibilities, team work, and motivation and payment systems.

## INTRODUCTION

The extensive mechanization of tree harvesting has significantly improved the forest workers' safety and health. The man with the chain saw has become a machine operator, well-protected in a cabin of good ergonomic standard. Successful improvements have been made regarding the classical problems of industrialized work such as noise, vibration, oil, and maintenance.

During recent years a new kind of occupational health problem has emerged in modern industrial work. It has been called the "overload syndrome", characterized by complaints and injuries to the neck, arms and cervical spine. Man is not "designed" to sit down and perform repetitive work for many hours in a fixed position. Even very light, short-cycle, movements of hands and arms may cause overload symptoms, and with prolonged exposure lead to injuries.

Reports from medical experts related to forestry indicate that these serious health problems now also affect today's specialized logging-machine operators. The objectives of this study were 1) to establish the prevalence of the overload syndrome among logging-machine operators in Sweden, and 2) evaluate some preventive and remedial actions in practice.

## MATERIALS AND METHODS

A "Health Risk Program" for forest work has been developed in order to improve health risk identification by systematic evaluation of the relationship between work and health complaints, and to create a base for decisions on different actions to reduce the health risk.

The program is based on a cooperation between the forestry Occupational Health Service (OHS) units in Sweden and the College of Forestry at the Swedish University of Agricultural Sciences. Joint studies are carried out in which the OHS units collect data and the College processes the results and coordinates the studies. The principal structure of the program is illustrated in figure 1.

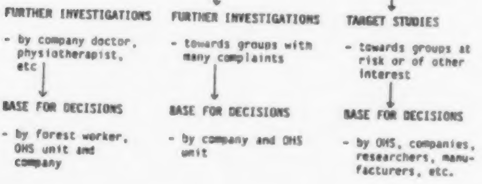
INDIVIDUAL LEVEL
GROUP LEVEL
TRADE LEVEL
INTERVIEW
SCREENING
BROAD SURVEY
- by company nurse
- structured by questionnaire
- questionnaire on health, work, living conditions
- data on ca. 6700 forest workers
IDENTIFICATION AND ANALYSES OF HEALTH RISKS
COMPANY REPORT
- analyses by safety-committee and OHS
- broad survey
- knowledge from OHS, research
FURTHER INVESTIGATIONS
FURTHER INVESTIGATIONS
TARGET STUDIES
- by company doctor, physiotherapist, etc
- towards groups with many complaints
- towards groups at risk or of other interest
BASE FOR DECISIONS
BASE FOR DECISIONS
BASE FOR DECISIONS
- by forest worker, OHS unit and company
- by company and OHS unit
- by OHS, companies, researchers, manufacturers, etc.

Figure 1. The principal structure of the Health Risk Program.
The total program includes health investigations of 6,700 workers, carried out by the Forestry Occupational Health Service (OHS).

In the screening part the employees fill in a standardized questionnaire, dealing with their work tasks, background, living conditions, state of health, and the possible connections between health problems and work. The answers are checked and completed in an interview by the OHS-nurse. Measurements of hearing and blood pressure are also made. If necessary, rehabilitative measures are taken by the OHS doctor or physiotherapist.

The data collected in the broad survey is used to identify and analyze health risks in forest work. So far 78 company/management districts have participated at 24 OHS units. A total of some 6,700 forest employees (among these 3,600 cutters, 1,200 machine operators and 600 supervisors) and 500 employees from other trades (industry, office work) have been studied (see figure 2). Two target studies of 300 machine operators (forwarders, processors, and harvesters) have been completed in order to get a more detailed picture of how the technical - ergonomic improvements of new machines, job rotation, and some individual factors affect the overload syndrome.

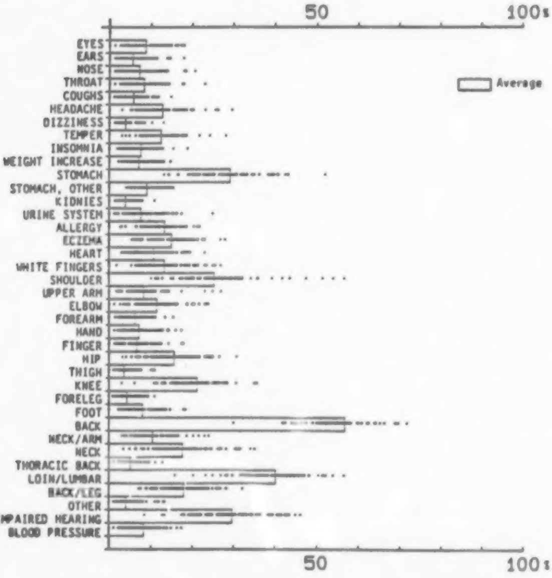

Figure 2. Results of health investigations of 6,700 forest employees at 78 companies/district. The percentile frequencies of forest employees with health complaints during the last 12 months. Each point represents one company/district. Only units with at least 20 forest employees are presented.

## RESULTS

### Health status

The machine operator's work is characterized by one-sided, repetitious, short-cycle working movements. He is sitting in a locked position many hours per day, working mostly with his arms and hands. The results of health investigations of 1,174 machine operators indicate a prevailing average overload syndrome of 50%, mainly characterized by neck/shoulder complaints. The complaints are also influenced by other work factors (working technique, psycho-social situation, etc).

The prevalance slightly increases with the age. (See figure 3).Even for young operators (20-25 years), however, the prevalence is high, i.e. 44%. The prevalence is highest (60%) in the age group 45-55 years, with a working time of 10-19 years as machine operators. The lowest value, 27%, refers to 35-44 years old operators, with a working time of 1-4 years.

The number of operators divided into groups refering to age and to years of work as a machine operator is shown in table 1. Groups in brackets are not included in figure 3.

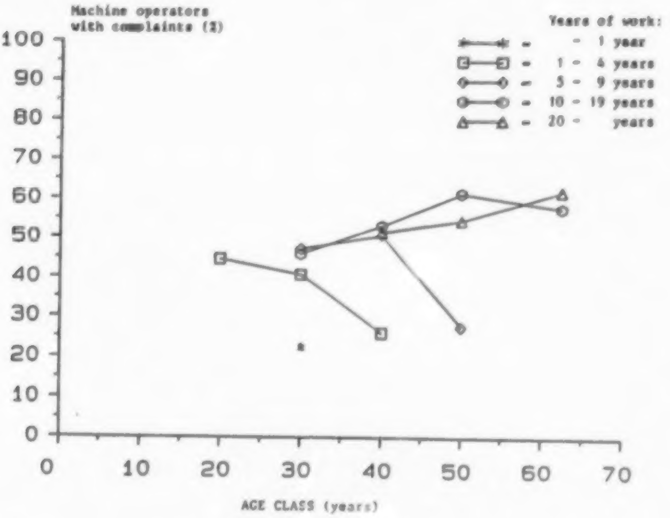

Figure 3. Logging machine operators (%) with neck/shoulder complaints vs their age and number of years at work.

Table 1. The total of 1,174 machine operators diveded into groups refering to age and to years of work as a machine operator.

| Time as machine operator. Years | Age < 24 | 25-34 | 35-44 | 45-54 | 55+ | Sum |
|---|---|---|---|---|---|---|
| < 1 | (13) | 22 | (9) | (2) | (0) | 46 |
| 1 - 4 | 56 | 81 | 50 | (11) | (2) | 200 |
| 5 - 9 | (13) | 142 | 85 | 40 | (5) | 285 |
| 10 - 19 | (0) | 74 | 224 | 140 | 52 | 490 |
| 20+ | (0) | (0) | 37 | 66 | 50 | 153 |
| Sum | 82 | 319 | 405 | 259 | 109 | 1 174 |

## Relation between health status and work environment

Analyses of the broad survey show that especially many of the processor and harvester operators had overload symptoms. Most of the operators (about 90%) stated that their complaints were related to the one-sided, static work movements, the controls and the seat. There was little difference between those operating new and old machines and between those working different time schedules. There were also small differences between those who did and those who did not do physical exercise in their spare time. However, the results from the broad survey are fairly rough and general. More knowledge was needed to get a base for recommendations on measures to be taken.

In order to get a more detailed picture of how the technical improvements of the machines, job rotation, and some individual factors affect the neck/shoulder complaints, two target studies were carried out.

## Operators of new logging machines

As stated in the introduction, the modern logging machines now used in Sweden have a significantly improved ergonomic standard, particularly regarding the design of the operator's work place in the cabin.

The objective of the first target study was to find out whether this favourable ergonomic development of new machines has had any positive impact on the overload syndrome among the machine operators.

The study was carried out in 1983-84. A "new machine" was defined as manufactured in 1978 or later. Only full time operators working with one "new machine" during at least the last two years were included. This means that the operators' exposure time from work with "new machines" was 2-4 years. A total of 169 operators of both forwarders (75), processors (57) and harvesters (37) participated. Health examinations and interviews were done by 11 larger OHS units from the whole country.

The results are summarized in table 2. Of the 169 machine operators, 43% indicated that they had symptoms of overload injuries at the time when they changed from the old to the new machine. After 2-4 years of working with the new machines, the prevalence figure had increased from 43 to 58%. There was no obvious difference between operators of forwarders, processors and harvesters. It might be noticed from the table that only 2% of the operators recovered and 10% improved after having changed to the new machine, while 13% deteriorated earlier symptoms and 17% developed new symptoms.

The target study on operators of new machines showed, in short, that the general technical-ergonomic improvements carried out in the newer machines have not been enough to relieve the operators of their symptoms and to prevent the development of new ones.

Table 2. The development of symptoms of overload injuries among 169 operators after 2-4 years of work with new machines. Percentage figures.

| | | | |
|---|---|---|---|
| Group 1. Operators with previous symptoms | | 43% | |
| After 2-4 years of work: | | | |
| recovered | 2% | | |
| improved | 10% | | |
| no change | 18% | | |
| deteriorated | 13% | | |
| Group 2. Operators without previous symptoms | | 57% | |
| After 2-4 years of work: | | | |
| new symptoms | 17% | | |
| still without symptoms | 40% | | |
| In total after 2-4 years of work with the new machine: | | | |
| Operators with symptoms: | | | 58% |
| Operators without symptoms: | | | 42% |

## Job rotation of logging-machine operators

In order to get a picture of how job rotation and some individual factors affect the overload syndrome a second target study was made in close collaboration with 3 larger OHS units. The study was limited to processor operators. Job rotation was defined as alternation between machine driving and other types of work; during the day (e.g. shift form), the week (e.g. rotation between machine work and chain-saw cutting), the season (e.g. planting, cleaning).

## Earlier studies

Few studies have been made in forestry of the relationship between job rotation and the overload syndrome. Studies in other trades often stress the positive impact from variation and pauses during work. However, few studies have dealt with actual job rotation. Job rotation has been considered to be something positive, for the health (physical and psychological) as well as for the long-term productivity. However, the former studies also pointed out several constraints for job rotation, such as:

- many older forest workers do not want to learn new types of work,
- machine operators do not want to "lend" their machine to others,
- practical problems, for instance in changing between machine work and chain-saw cutting,
- unsuitable wage forms,
- education and training of the participants,
- difficulties in finding meaningful work tasks to rotate to, for instance during the shift "on the ground" in the 3-hour shift (see figure 4).

## The broad survey

A detailed analysis of the 431 processor operators that so far had participated in the broad survey gave a picture of the situation where operators were working with job rotation. The analysis showed:

- a tendency that job rotation was more common among the younger and those with short machine operating experience,
- that job rotation was more common among trained operators,
- that job rotation was as common in partly mechanized as in fully mechanized systems,
- that job rotation was as common among those working on piece rate as among those working on time wage,
- that more of those who rotate were physically active in their spare time.

## The second target study

A total of 110 processor operators participated in the target study. The objective was to study the effect of job rotation (especially the 3-hour shift, see figure 4) and some individual factors on the symptoms of overload injuries.

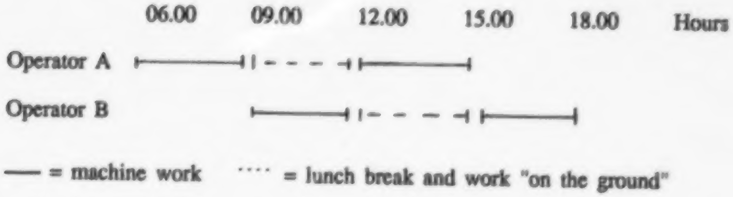

Figure 4. The organization of the 3-hour shift. Two operators are assigned to one machine, and they rotate in 3-hour periods. Operator A starts at 6 a.m, and operator B at 9 a.m. During the 3-hours "on the ground" the operator takes his lunch break and carries out repairs, planning, chain-saw cutting, etc.

Of the 110 machine operators in the study, 76 had worked the 3-hour shift during at least the last two years (on an average 3-4 years) and 25 operators a regular 8-hour shift. Nine operators had various shift forms, and are not included in this analysis. The results are summarized in table 3. The figures indicate that the effect on the overload symptoms from changing from a regular 8-hour shift to the 3-hour shift is limited and uncertain (prevalence figure 40% and 44% respectively, after 3-4 years of work). These figures are influenced by the fact that more of those working an 8-hour shift (24%) had recovered than had those working a 3-hour shift (12%). In total an equal share in the two groups had improved or recovered. On the other hand, the 3-hour shift seems to have a positive effect on earlier established symptoms. Among the 30% of the operators who had established symptoms before they started to work the 3-hour shift, 74% improved or recovered. The corresponding figure among the 22% who established symptoms when they were working the 3-hour shift was 47% (3 operators had given incomplete answers).

Table 3. The development of symptoms of overload injuries among procesor operators after changing from regular 8-hour shift to 3-hour shift (3-4 years of work). Percentage figures.

| | 3-hour shift (76 operators) | 8-hour shift (25 operators) |
|---|---|---|
| Operators with previous symptoms: | | |
| recovered | 12 | 24 |
| improved | 22 | 8 |
| no change | 21 | 28 |
| deteriorated | 1 | 4 |
| Operators without previous symptoms | 44 | 36 |
| | 100 % | 100 % |
| In total after 3-4 years of work: | | |
| Operators with symptoms | 44 | 40 |
| Operators without symptoms | 56 | 60 |
| | 100 % | 100 % |

The results indicate that the 3-hour shift, as a general measure, had not radically solved the neck/shoulder problems. However, it may have positive effects on some operators with established complaints.

Pauses and micro-pauses during work are not very common. Fourty-nine percent of the processor operators seldom or never released the controls and 40% seldom or never stepped out of their machine during the work shift.

One reason that the 3-hour shift has not lead to the expected decrease in complaints could be that the operators work more intensively during the 3 running hours. Operators, who worked the 3-hour shift stepped out of the machine and let go of the handles significantly less than did the operators working regular 8-hour shift.

## PRACTICAL IMPLICATIONS

For measures in practice to reduce the prevailing health risks, it is feasible to group the various actions into the following three categories:

- Technical
- Individual
- Organizational

The work situation and the work factors change over time. The effect on the individual complaint can be described as in figure 5. A certain work produces specific risks for development of complaints. The "health risks" from various factors are added to each other. Each individual has a "limit" above which he will develop a complaint. This "limit" depends on the physical and psychological status of the individual as well as on his body's resistibility to stress. The "limit" can change, for instance; a severe cold, problems at home, etc might lower the limit; physical training, etc might raise the limit.

The actual development of a complaint or illness also depends on the time above the "limit". Working high above the limit may result in a complaint after only a short period of time (e.g. a cutter taking down a hanging tree using his ultimate strength in an awkward position, might get an acute back pain). Working just at the limit might result in a complaint only after a very long period of time (e.g. a skidder operator working with small tensions in the muscles, might take up to 20 years to develop a complaint). Since the factors are added to each other, a factor with a high "risk" to the employee can be compensated by a low "risk" from another factor. See figure 5.

The intention of figure 5 is to serve as a "pedagogic model". This model is now being used to facilitate and motivate the implementation of measures in Swedish forestry. New projects have recently been started at several forest companies.

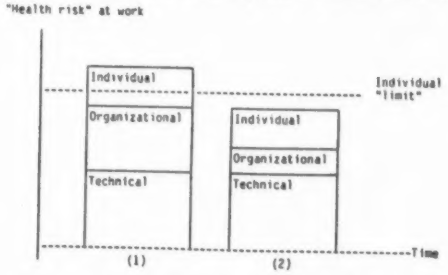

Figure 5. The multiple effect on the health risks of different individual, organizational and technical work factors, related to the time. The individual "limit" is the limit above which a complaint may be developed.

(1) = In this case the risk for neck/shoulder complaints is evident for the operator.

(2) = The work organization has been changed for the operator, e.g. by job rotation between machine work and other work tasks (decreases the time of exposure for the high tensions in the neck/shoulder muscles). There is no risk for complaints at present.

The results of the Health Risk Program reported in this paper indicate an alarming high prevailing average overload syndrome figure of 50% among the forest workers. The results and the experiences so far also indicate that a whole battery of measures is needed to radically improve this serious situation, including new technology and new forms of work organization, as well as motivation of the machine operator to influence his own situation.

Single measures might be positive, but are not enough. To be effective, the full program of measures must be carried out, and be adapted individually to each machine operator. Rehabilitative measures should be taken as soon as possible after the complaint debut.
Improved technology/ergonomics is needed. This is especially regarding the sitting working posture in the cabin, i.e. design of the arms of the chair, controls and instruments. Reduction of the whole-body vibrations is also important.

Important individual factors are working techniques, micropauses and physical fitness. Support from a physioterapist is essential. It might even be necessary to introduce physical training during the work shift .

New work organization is the most difficult part of the proposed battery of measures to realize in practice, but is also the part which probably has the highest potential for improving the situation. Examples of issues to address are design and length of the working shift, job rotation, work tasks and responsibilities, team work, and motivation and payment systems.

This is a real challenge to undertake, both for the researchers and the companies. The experience so far indicates that the difficulties are large and the long-term effects uncertain. One particular difficulty is to develop new methods for evaluating the effect of measures undertaken. The effects regarding several factors should be evaluated, not only health aspects, but also productivity, quality of the work, organization, economy etc. Evaluations from a health risk point of view are complicated in this case, for overload complaints and injuries often take a long time to develop. The fact is that the positive effects of various measures are often short-termed and might weaken and disappear with the time.

Thus far, we have learned from the current attempts and trials at different forest companies that in order to get the full effect of the program of suggested measures it is necessary to start by increasing the motivation and by improving the cooperation of all parties involved. This means not only the researchers and the manufacturers of logging machines as up to now, but especially also the forest company, management, supervisors in the field, and the logging-machine operators themselves.

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This papers is based mainly on results from the current Health Risk Program at the Swedish College of Forestry, Garpenberg. Details of the Program and a comprehensive list of references are given in Pontén, B. 1988: Health Risks in Forest Work - A Program for Action. Report No 177, Department of Operational Efficiency, College of Forestry, S-770 73 Garpenberg, Sweden.

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# REVIEW OF AND OUTLOOK ON ERGONOMIC RESEARCH IN FORESTRY IN DEVELOPING COUNTRIES

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At previous IUFRO meetings, the author looked into the need for ergonomic research in forestry in tropical developing countries (Strehlke, 1971, 1981 and 1986). He was also involved in the courses organised by the Dutch-funded Programme for the Promotion of Ergonomics in the Tropics (PET), held in 1982, 1984, 1986 and 1988. In 1988 and 1989, he participated in the preparation of plans for a Special Programme for Forestry Working Environment and Techniques (FWET) through the Swedish International Development Authority (SIDA) in collaboration with the Swedish University of Agricultural Sciences.

Against this background, progress made to introduce ergonomic research in forestry in the developing countries since the 18th IUFRO World Congress, held in 1986, is briefly discussed and conclusions are drawn for future research in this field.

## IUFRO meetings in Brazil and Pakistan, 1987

IUFRO group leaders who organised the symposia on Harvesting, Transport, Ergonomics and Safety in Plantation Logging, held in Curitiba, Brazil, and on the Role of Forest Research in Solving Socio-economic Problems in the Himalayan Region, held in Peshawar, Pakistan, must be congratulated for attracting large numbers of representatives of the forestry sector who, among other things, discussed ergonomic problems of forestry work. This special focus had never been given in the past to ergonomics in developing countries within IUFRO symposia. Experience was shared by research workers from industrialised and developing countries.

The symposium in Brazil revealed that large-scale forest owners are beginning to recognise the links between labour and machine productivity, cost efficiency and working conditions. One report dealt with progress in accident prevention made by a forestry company after the introduction of an Occupational Safety and Health Monitoring Unit, as illustrated by a survey of accidents between 1968 and 1987 (Costa et al., 1987). Another company studied back pain among chain saw operators and the impact of shift work schedules on truck drivers with a view to improving operational efficiency within acceptable levels of workload (Bassini et al., 1987).

In the Pakistan symposium, research on ergonomics in forestry carried out by Indian and Pakistani research workers between the mid-1970s and the mid-1980s was reported upon (Ayaz, 1987; Sood, 1987). In both cases, physical workload measurement had been carried out in wood harvesting operations and recommendations had been made concerning improved tools, techniques, training and nutrition, as well as further research. However, a significant follow-up had not been possible, particularly as regards applying the findings in practice. The meeting recommended that:

> "Research in ergonomics should be strengthened and extended beyond harvesting to other forest activities as a means of improving working conditions and efficiency. Studies are needed in particular on the nutrition, occupational health and safety and climatic stress of forest workers. Ergonomic research should also include female workers. More emphasis must be given to apply findings from forest research in practical forestry through the training of field staff."

## Research-related activities promoted by the ILO

Attempts have been made by the ILO to incorporate ergonomic studies in ILO technical co-operation projects and - in collaboration with the PET programme - to support studies to be carried out by former PET fellows (Strehlke, 1988). The Guide-lines on Ergonomic Study in Forestry for Research Workers in Developing Countries, published by the ILO in 1989 (Apud, et al., 1989) are assisting in such activities.

The following problems were dealt with in this work:

- In Zambia, in the context of an ILO/World Bank Forestry and Forest Industries Training Project, studies were carried out on the physical workload in logging and on noise and hearing impairment in sawmilling (Staal, 1989). Workplaces in sawmilling were evaluated by means of an ergonomic checklist. An accident reporting system was introduced, as well as a system of providing lunch for workers, whose responses to the latter were appraised through an enquiry.

- In Fiji, through an ILO/Finland logging training project, the preparation of a logging safety code was launched and studies were carried out on motivation and attitudes of forest workers as regards employment in forestry and training.

- Through PET fellows, studies on occupational safety and health and ergonomics were carried out in Nigeria (on logging and sawmilling), in Pakistan (on small-scale sawmilling) and in China (on logging). In Nigeria, this work is at present continuing and will lead to a national workshop on occupational safety and health and ergonomics in logging and sawmilling, to be held in June 1990, which is being organised in collaboration with the PET programme and the ILO. At the workshop, the results and findings from half a dozen studies will be presented to and discussed with the industry and the authorities concerned.

Furthermore, the following are under preparation:

- An ILO/Netherlands technical co-operation project on technology and training in afforestation and soil conservation to be located in the North-West Frontier Province of Pakistan which aims at improving labour productivity and working conditions on the basis of work study and ergonomic study.
- The publication and dissemination of a monograph entitled "Ergonomics applied to forestry - the Chilean case", in which the work done by Elias Apud over two decades and its impact on forestry will be reflected (in response to a recommendation of the Finland/ILO/IUFRO workshop, 1985, that "knowledge about examples of the successful application of the results of work study and ergonomic study should be widely disseminated").

In addition, it should be noted that, following up on an FAO/Finland survey and consultation on forest harvesting training, a previous proposal was revived to organise regional courses in work study and forestry through a technical co-operation project prepared by the ILO for which funding may become available in 1990. It has been envisaged to establish and publish in the framework of such a project, guide-lines for work study in forestry in developing countries to supplement the ILO Guide-Lines on Ergonomic Study mentioned above.

Another project proposal suggested by the ILO within the FAO/Finland forestry harvesting training programme concerns improvement of occupational safety and health in wood harvesting through case studies in selected enterprises, followed up by national workshops to discuss the findings and to draw up programmes for action at national and enterprise level.

## The Programme for Forestry Working Environment and Techniques proposed by Sweden

In the past, Swedish research workers have carried out repeatedly, on an ad hoc basis, ergonomic studies in forestry related to a logging training project in India, the most recent ones in 1985 on manual transport in a timber depot (Andersson, 1987).

A new initiative was taken in 1988 by SIDA through Lisbet Bostrand to prepare a special programme for Forestry Working Environment and Techniques (FWET). This is a logical step forward from findings from studies carried out by SIDA in a technical co-operation project in Vietnam which suffered from poor labour productivity as a result of unacceptable working conditions. Joint efforts by the donor and the recipient country had helped to improve this situation (Bostrand, 1986).

The lesson drawn from the experience in Vietnam was that technical co-operation projects provide an excellent opportunity to introduce both improved technology and improved working conditions. However, the close relationship between labour productivity and working conditions which is well understood in the industrialised countries up until now has been largely overlooked in the developing countries.

The FWET programme is meant as a systematic approach to deal with working environment and technology in four countries where SIDA is involved in forestry and small-scale sawmilling. This will be done in the first instance through research and studies such as ergonomic surveys of workplaces, work study, workload measurement, investigation of accidents and occupational diseases. Secondly, on the basis of the findings, steps will be taken to upgrade working environment and technology with a view to making jobs easier and safer and to increase operational efficiency. Thirdly, the results will be disseminated through training.

Preparation of the FWET programme started in 1988 on the basis of a survey of relevant activities and literature (Cedergren, 1989). A workshop took place in 1989 with representatives of the project countries concerned in which FAO and ILO also assisted, to formulate concrete project proposals for the four different programme countries. It is hoped that finance will become available in 1990 to implement the programme.

## Some conclusions from past research efforts and suggestions for future work

Looking at the attempts made to launch ergonomic research in forestry in developing countries since the last IUFRO World Congress, it can be stated that some promising approaches have been tried which now require further strengthening.

In the absence of support from IUFRO's Special Programme for Developing Countries which concentrates its limited resources on other research areas, funding must be secured elsewhere. It appears that this is best done in the context of technical co-operation projects which offer scope for research, for the application of research findings in practice and for their dissemination through training.

Such projects should preferably involve research institutions from the donor and the recipient country. Special emphasis must be given to link up research and practice and to consider research findings in the curricula of technical and vocational training. Particularly state forest corporations and private companies can become strong supporters of ergonomic research if they can be convinced that it pays to provide better working conditions.

Through the Tropical Forestry Action Plan, with its orientation towards a wide range of activities embracing the whole forestry and wood industries, it has not been possible to reinforce research in ergonomics. However, this may be feasible under the projects which are being prepared by the International Tropical Timber Office (ITTO) on the sustained management of tropical forests. Sustained management requires sustained harvesting and this in turn requires a stable and qualified labour force in order to minimise damage to felled trees, remaining crop and site - but a stable and qualified labour force cannot be maintained if working conditions are unfavourable. Hence, the challenge to consider ergonomics in research and demonstration projects on sustained tropical forest management.

Previously, ergonomic research on forestry in developing countries concentrated on workload measurement when using different working tools, techniques and methods by recording heart-rate and oxygen consumption. This helped to identify energy-saving technology and to keep physical demands of work in balance with the worker's fitness and nutrition. There is continuing need for this type of research.

However, more recently, ergonomic checklists have also been used as a simple means of ergonomic analysis of workplaces leading more directly to practical improvements. There is much scope for extending this approach on the basis of existing checklists (Apud et al., 1989).

Little progress has as yet been made on accident studies. Though suitable models for the introduction of accident recording systems exist by now (Apud et al., 1989), reliable and complete records can only be expected if management fully supports the system and if initially those who fill in the records (foremen, supervisors) are systematically and carefully instructed on why and how to do this.

Repeatedly suggested but still missing is research on the impact of hot climate on forest work. To what extent does heat stress impair working capacity, what can be done by means of work organisation or otherwise to keep heat stress within tolerable limits and avoid excessive interference with working productivity? These issues would finally merit becoming the subject of a comprehensive special research project which should materialise within the next few years. Funding, though, may continue to pose problems.

As regards attempts to promote ergonomic research through individual PET fellows, they have by and large turned out to be more difficult than originally expected, even in cases where acceptable project plans had been prepared; the reason is that in most cases the necessary institutional support is insufficient or missing. Research workers who were able to specialise more deeply in the subject and who are more firmly established in teaching and research institutions (e.g. Apud/Chile, Aluma/Uganda, Ayaz/Pakistan) are better placed to do ergonomic research. PET fellows, incidentally, have been quite successful in promoting training in ergonomics.

To conclude, it should be stressed that of course further international meetings are desirable at regional levels as well as publications addressing an international audience to promote exchanges and to share experience in research in ergonomics. The IUFRO meetings held in 1987 in Brazil and Pakistan which were supported by various donors, by the host countries and by several international organisations, are examples to be followed. There should be one such meeting in each developing region between the 19th and the 20th IUFRO World Congresses.

The author wishes to take this opportunity to gratefully acknowledge the excellent collaboration which he has enjoyed in his position as ILO Forestry and Wood Industries Specialist with IUFRO Division 3 in general and the project group on ergonomics and the subject group on forest operations in the tropics in particular. Thanks to this collaboration, activities have been strengthened on both sides. It is hoped that after his retirement from the ILO, the close working links between IUFRO, PET, donors of technical co-operation and the ILO will continue for the benefit of the people working in the forests of developing countries.

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# THE COSTS AND FUTURE PROFITABILITY OF SMALL SCALE FARM FORESTRY IN SCOTLAND.

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## SUMMARY

Britain, one of the least afforested countries, traditionally manages forestry and agriculture separately. In 1988 grant schemes were introduced to encourage tree planting on farm land. A survey of the establishment costs of 39 Scottish farms planting woods under the new Farm Woodland Scheme showed that total costs per hectare were £1450 (£319-£4671/ha). Costs were reduced by using farm labour and cheat fencing, while high costs involved the use of contractors. Fencing was a considerable cost £100-£1077/ha for materials and inclusive of contractors labour £133-£1972/ha. Farmers gave amenity and recreation as their primary reason for planting. The potential profitability on a lowland site for a full rotation was calculated over 50 years for Sycamore and Sitka Spruce and 62 years for Scots Pine. The mean cash flows give an estimate of profit, comparable to the Helsinki working groups guidelines, were £131/ha, £379/ha and £245/ha respectively. If discounted at 6% and expressed as an annuity, the convention in Britain, these were - £60, £11 and - £39/ha respectively. When the new Farm Woodland Scheme planting grants and annual payments are included the annuities become £185/ha, £179/ha and £123/ha respectively. Only in the case of Sycamore for which the planting grant is higher did these equal the mean cash flows. The lack of tradition in and perceived profitability of farm foresty in Britain may explain the lack of woodlands on farms.

## INTRODUCTION

This paper presents interim results of a survey of establishment costs of new woodlands on farms in Scotland in 1988/89 under the recently introduced Farm Woodlands Scheme. It also presents projected profitability of three small scale woodlots, of Scots Pine (Pinus sylvestris), Sitka Spruce (Picea sitchensis) and Sycamore (Acer pseudoplatanus). For these systems the income, expenditure and net cash flow for each year are given. Calculated from this are: the mean cash flow as an estimate of profit (comparable to the guidelines of the Helsinki working group), the discounted net present value and equivalent annuity (the conventional means of appraising United Kingdom (U.K.) forestry investment). These results are presented net of any grants and with both of the currently available grants for comparison.

The data are preceded by a brief commentary on U.K. farm forestry and a description of the recently introduced grants for farm forestry and the relevant taxation changes.

## BACKGROUND

Britain is one of the least afforested countries in Europe with only 24.4 million hectares of forest, 9% of land area. State forests account for 43% of the area and 73% of woodland is coniferous. Most of these forests are in large blocks in the hills and uplands of Scotland and Wales. There is very little woodland on farms.

Until the middle of this century the majority of farmers rented their land from a landowner whose 'estate' would comprise several farms, indeed some estates would cover thousands of hectares and hundreds of farms. The farmer would only rent the farmland. Any woodland would be owned and managed by the owner with one or more foresters on the estate. Particularly since 1940 an increasing number of farmers have purchased their farms becoming owner-occupiers of both the farmland and woodland.

On lowground farms much of the woodland is mature or overmature broadleaves originally planted by the estate primarily for amenity and field sports. These plantations are of limited commercial value. Farmers tend to be unskilled in forestry so the woodland has become neglected or been felled. If felled the ground might be cleared for agriculture sometimes with grant aid, or perhaps replanted using any available planting grants. Replanting has frequently been with Sitka Spruce or other conifers primarily to provide shelter.

There is therefore little tradition, experience or interest by U.K. farmers in forestry. Only a few would practise managed farm forestry. Forestry has been on a large scale managed separately from agriculture by the Forestry Commission, private companies and estates.

The European Economic Community (EEC) have been attempting to reduce the cost of agricultural support under the Common Agricultural

Policy (CAP) with production quotas, price reductions and measures to take agricultural land out of production. Forestry has been considered by both farmers and legislators as an alternative use for agricultural land, increasing interest in small scale forestry on farms.

## GRANT AID FOR FARM FORESTRY

In April 1988 the British government replaced the previous planting grants provided under the 'Forestry Grant Scheme' and 'Broadleaved Woodland Grant Scheme' with the 'Woodland Grant Scheme' which also covers restocking and rehabilitation of existing woodland either by planting or natural regeneration. In October 1988 the 'Farm Woodland Grant Scheme' was announced , which provides both planting grants and annual payments to encourage farmers to plant woodland on agricultural land. Under the set-aside scheme, also introduced in 1988, woodland is a permissible use of agricultural land being set-aside.

The main details and rates of grant are as follows.

### 1 Woodland Grant Scheme

Administered by the Forestry Commission the scheme provides grant for individual areas of 0.25 ha and over, both owned and tenanted. Grant will be paid according to the total area to be planted within each separate block to the nearest 0.1 ha , as shown in Table 1.

In mixed plantations the rate of grant is determined by the proportion of conifers and broadleaves planted. These grants are paid in three instalments: 70% on completion of planting and, subject to satisfactory establishment and maintenance, 20% after 5 years and 10% after 10 years.

A supplement of £200/ha is payable with the first instalment when the planting is on arable or improved grassland.

To qualify, a 5 year plan of operation must be approved by the Forestry Commission. The main conditions are:- 1) Timber production must be one of the objectives of planting. 2) The proposed plan of operations must adhere to sound forestry practice. 3) The landscape and nature conservation impact of planting should be considered. 4) The minimum plantation width is normally 30 m. 5) Satisfactory establishment must be achieved. 6) A minimum of 5% broadleaves must be included and shown on the plan.

## 2 Farm Woodland Scheme

There are two sets of grants payable under this scheme

i) Planting Grants paid by the Forestry Commission shown in table 2.

These grants are paid in three instalments: 70% on completion of planting and, subject to satisfactory establishment, 20% after 5 years and 10% after 10 years. As for the Woodland Grant Scheme grant is paid on each separate block. In mixed woodlands grants are calculated in proportion to the area of conifers and broadleaves planted. For conifers there must be a minimum of 5% broadleaves. There is a minimum of 3 ha and maximum of 40 ha per farm unit with a minimum block size of 1 ha. Planting may be spread over 3 years.

To receive the above rates of grant there must be a minimum of 2250 conifers per hectare and 1100 broadleaves, however lower planting densities may be permitted if considered acceptable by the Forestry Commission.

ii) Annual Payments are made by the Department of Agriculture and Fisheries for Scotland (DAFS) or in the rest of Britain by the Ministry of Agriculture Fisheries and Food (MAFF) as shown in Table 3.

## 3 Set-aside

There are two options for tree planting under the Set-Aside scheme administered by DAFS or MAFF.

i) Direct Set-Aside to Woodland when planting grants are payable as in the Woodland Grant Scheme (Table 1) but no better land supplement is available. In addition there are annual payments of £180/ha on Less Favoured land and £200/ha elsewhere for the duration of the set-aside agreement-currently a maximum of 5 years.

ii) Set-Aside through the Farm Woodland Scheme. This is identical to the Farm Woodland Scheme described above. The land planted will however, if eligible as set-aside, form part of the set-aside area for the purposes and requirements of the set-aside scheme.

## FARM WOODLAND SCHEME SURVEY - INTERIM RESULTS

Of the approved applications under the Farm Woodlands Scheme 39 farms in Scotland have been surveyed to obtain data on the cost of establishment of the woods.

The average total woodland on these farms will after completion of FWS planting be 32 ha of which 6.7 ha will be new woodland (table 4). Table 5 shows that conifers have been the predominant species on these farms in the past. Under the Farm Woodland Scheme, however, broadleaves are the predominant species being planted (table 6). Agricultural enterprises would in all cases be more important than forestry, but it is of note that in 40% of cases the farm was not the owner's major source of income. In general the investment was not being made from farm income but from reserves or other income sources.

The total cost per farm of planting so far completed is given in Table 7. Some farms have not yet completed their planting programme under the scheme. There is quite a range in the total investment and the costs per hectare incurred in establishment.

The farms were divided into those planting less than 5 ha or more than 5 ha. Only one farm (32.4ha) was planting more than 20 ha. The average areas and plot size to be planted under the scheme are shown in Table 8. On many farms where more than 5 ha is to be planted the planting comprises several distinct plots each of at least 1 ha. The planting grant is of course related to the individual plot size and not to the total area being planted per farm under the scheme. While the average investment (total cost) per farm is obviously greater for those with 5 ha and above, the costs per hectare are surprisingly similar. When fencing, which is proportionally greater for smaller areas is excluded (table7c) there is only a small difference. As the average plot sizes are only slightly greater for those planting over 5 ha (table 8) this is not surprising. Where home labour has been used costs shown are considerably lower as the information was not available to apportion labour costs to the woodland enterprise.  The real saving, which would not be as great, is unknown.

Table 9 shows the component costs of the woodland establishment. The majority of farms required no special preparation before planting. Where ploughing was carried out by a contractor or drainage was required (one farm in each category) it cost £34-35/ha.

There was a wide variation in tree costs per hectare, due to the range of species between farms and the increased costs associated with obtaining the small quantities of individual species required to plant mixed woodland. In some cases a high planting rate was used, increasing the cost per hectare (e.g. 1962 broadleaves/ha costing £538/ha).

Tree shelters are individual plastic tubes placed over the tree and fixed to a stake. They vary in height and diameter depending upon the protection required, the tree species and the expected life of the tube, which eventually disintegrates leaving a well grown young tree. They can provide protection from rabbits, hares, roe deer and sheep thereby saving on or eliminating the fencing costs. When a small area with a long perimeter is to be planted at low density, tubes can be cheaper than fencing. As the plastic tubes also provide a mini greenhouse for the trees, they may be used where the area is fenced to provide enhanced protection and growth rates. The wide range of costs for shelters reflects the proportion of trees so protected and the shelter type.

The cost of materials per hectare for weeding is largely independent of the total area. The cost of contractors or casual labour to plant the trees was reduced where more than 5 ha was being planted but varied presumably with the skill of the labour. One farmer paid only £73/ha.

Fencing costs are a significant item, with materials alone often equal to the cost of the trees. The fencing required varies in cost for materials from none on all- arable farms where tree shelters are used, through simple stock fencing at £1/m, fencing for sheep £1.1/m, rabbit netting £1.30/m, to full deer fencing with rabbit netting at £1.54/m. On many farms rabbit netting will be essential. The small plot size implies a high perimeter to area ratio, but in many cases some fencing already exists as a field boundary, hence the low cost per hectare for some blocks. Contractors' labour charges will be at least 62p-£1/m depending on fence type. Insurance is a small cost which is directly proportional to area. Costs are not available for farm labour nor disaggregated further.

## ESTIMATION OF POTENTIAL PROFITABILITY OF FARM FORESTRY

It is conventional in considering forestry in the United Kingdom to discount the future costs and revenue. The costs and projected revenue over the rotation of the block are calculated; these are then discounted to a net present value using a real (i.e. excluding inflation ) interest rate.

Tables 11, 12 and 13 show the cash inflows and outflows, i.e. expenditure and income per hectare over the rotation of the three different species. Also shown are the appropriate planting grants under the Woodland Grant Scheme and the planting grants and annual payments under the Farm Woodland Scheme. Three annual net cash flows are then shown - WGS where the Woodland Grant Scheme planting grants have been received, FWS where the Farm Woodland Scheme planting grants and annual payments have been received and finally the situation net of all grants for international comparison. This last is extremely unlikely to occur in practice in the U.K..

To be comparable to the guidelines prepared by the Helsinki working party, the mean cash flows per hectare are shown. These can be considered to be the profit per hectare before management provided by the farmer, if the farm had an even spread of age of woodlots. The net present value is the discounted total for all the annual cash flows at 6% real interest rate. The annuity is the average annual equivalent cash flow or profit to the net present value.

For each system a 2 ha block was used in compiling costs. It is thus eligible for the highest rate of planting grant in the Farm Woodland Scheme. It is also the average size of plot planted on the farms surveyed and would be representative of lowland farm woodland. All costs are at 1988 prices.

Fencing costs assume rabbit proof fencing and includes farm labour at £110/ week (including social costs), as do the planting costs.

Timber prices are taken for the timber sold standing as very few farmers harvest commercial timber on their farms. Prices for conifers are based on Table 10. Costs for each thinning for marking, measuring and clearing up are £50/ha, but the first thinning of conifers has no commercial value. The costs of final felling vary with the volume and are shown for each example. Timber income from conifers is reduced by 5% to allow for the required broadleaved content. The hardwood market in Scotland is limited: for thinnings £10·15/cu m. might be obtainable with the final felling going for veneer or furniture the return could be £30/cu m.

Table 11 gives the profitability of Sycamore grown on poor quality arable ground on a lowland farm where yield class 8 should be attained. Over a 50 year rotation 28cu m would be harvested at each thinning and 241cu m at final harvest. Trees would be planted at 2m x 2m spacing making 2500/ha.

Table 12 is for Sitka Spruce, the most common commercial conifer in Scotland. Assuming similar land quality to the Sycamore, 70cu m should be harvested at each thinning, the final yield 634cu m. Planting rate would be 2500/ha as for Sycamore with 5% broadleaves included.

Table 13 is for Scots Pine, which is a native species well suited to the gravelly soils of Eastern Scotland. On a reasonable site Yield Class 14 might be achieved giving 49cu m/ha at thinning and 499cu m at final felling. However rotation length is 62 years. To meet grant conditions 5% broadleaves would be included in the 2500 trees /ha planted.

From the mean cash flows it can be seen that the high yielding Sitka gives the greatest profit (£379/ha) followed by the Scots Pine (£245/ha) then the Sycamore (£131/ha). The Farm Woodland Scheme grants and annual payments more than double the profit from the Sycamore, but have a less marked effect on the conifers due to the lower planting grant and shorter duration of annual payments.

When the cash flows are discounted as is the convention in the U.K. the Scots Pine with its long rotation and Sycamore with its low yield produce negative returns, while the higher yielding Sitka only returns £11/ha. The planting grants for the Woodland Grant Scheme help but it is the Farm Woodland Grant Scheme annual payments in the early years of the rotation which bring more reasonable profits. With falling agricultural returns it is therefore not surprising that the introduction of the Farm Woodland Scheme has stimulated some interest in the planting of small woodland plots on farms, particularly where although suitable for trees, the agricultural returns are marginal.

The annuities obtainable even with the assistance of the Farm Woodland Scheme are still considerably less than the mean cash flows obtained without grant. As there is relatively little existing woodland on British farms there is little immediate income available from forestry thus farmers perceive the woodlands as a one- off investment. Although timber production must be an objective for planting under the scheme many of the farmers in the survey gave amenity and recreation as their primary objectives. With so little existing farm woodland and such small areas being planted, farm woodland is unlikely to be or become a consistent or major source of farm income. Farmers' investment in forestry equipment is usually small or non existent, nor are they particularly skilled foresters. Thus experienced contractors are frequently used especially for the final harvest.

It is therefore difficult to obtain more detailed information on profitability according to the guidelines of the Helsinki working party, thus forestry investment appears less attractive when internal rates are considered.

Table 1: Woodland Grant Scheme - Planting Grants

| Area approved for Planting (ha) | Rate of Grant Conifers (£/ha) | Rate of Grant Broadleaves (£/ha) |
|---|---|---|
| 0.25 - 0.9 | 1.005 | 1.575 |
| 1.0 - 2.9 | 880 | 1.375 |
| 3.0 - 9.9 | 795 | 1.175 |
| 10 and Over | 615 | 975 |

Table 2: Farm Woodland Scheme - Plant Grants

| Area of Block (ha) | Rate of Grant Conifers (£/ha) | Rate of Grant Broadleaves (£/ha) |
|---|---|---|
| 1.0 - 2.9 | 505 | 1.375 |
| 3.0 - 9.9 | 420 | 1.175 |
| 10.0 and Over | 240 | 975 |

Table 3: Farm Woodland Scheme - Annual Payment

**Arable/Improved Grassland** (re-seeded within the last 10 years).

| | |
|---|---|
| LFA - Severely Disadvantaged | £100/ha/year |
| LFA - Disadvantaged | £150/ha/year |
| Elsewhere (lowland) | £190/ha/year |

**Unimproved Land**

| | |
|---|---|
| Less-Favoured Areas | £ 30/ha/year |

**Duration of Annual Payments**

| | |
|---|---|
| Pure crops of oak and beech (up to 10% other broadleaves allowable) | 40 years |
| Other pure broadleaved crops and mixtures containing more than 50% broadleaves) | 30 years |
| Pure conifer crops and mixtures containing less than 50% broadleaves | 20 years |
| Coppice | 10 years |

Table 4: Total Woodland by size group

| Group ha | No. | Total wood ha | av. total wood | fws wood (% of total) | av. fws wood |
|---|---|---|---|---|---|
| <5 | 4 | 15.2 | 3.8 | 13.2 (87) | 3.3 |
| 5<20 | 16 | 155.7 | 9.7 | 87.1 (56) | 5.4 |
| 20<50 | 12 | 399.8 | 33.3 | 81.6 (20) | 6.8 |
| 50<100 | 5 | 385.2 | 77.0 | 31.5 ( 8) | 6.3 |
| 100<200 | 2 | 292.2 | 146.1 | 48.1 (16) | 24.1 |
| >200 | - | | | | |
| Total % | 39 | 1248.1 | 32 | 261.5 (21) | 6.7 |

Table 5: Category of Existing Woodland in ha (no of farms)

| Age | B'leaved | Mainly B'leaved | Mainly Conifer | Conifer | Other Mixed |
|---|---|---|---|---|---|
| <10yrs | 4.9 (2) | 6.8 (3) | 20.0 (1) | 34.1 (2) | 1.6 (1) |
| 10-60yrs | 0.5 (1) | - | 350.2 (13) | 62.9 (8) | 56.7 (1) |
| 60+yrs | 108.2(16) | 131.2 (7) | 209.3 (4) | - | - |
| | 113.6 | 138.0 | 579.5 | 97.0 | 58.3 |

Table 6: Proportions of Broadleaves and Conifers planted by area as %

| | Broadleaves | Conifers |
|---|---|---|
| All approved applications | 60 | 40 |
| Of sample < 5 ha | 78 | 22 |
| > 5 ha | 63 | 37 |

| | All Broadleaves | Mixtures >50% Broadleaves | <50% Broadleaves |
|---|---|---|---|
| < 5 ha | 43 | 48 | 9 |
| > 5 ha | 33.3 | 33.3 | 33.3 |

Table 7: Total Costs (£) of Planting completed (36 farms)

(a) All farms

| | Mean | Range |
|---|---|---|
| av. total cost per farm | 6501 | 1085 - 29895 |
| av. cost per farm per ha planted | 1457 | 319 - 4671 |

(b) Planting < 5 ha (25 farms)

| | | |
|---|---|---|
| av. total cost per farm | 3853 | 1085 - 9259 |
| av. cost per farm per ha planted | 1458 | 319 - 4000 |

Planting 5 ha + (11 farms)

| | | |
|---|---|---|
| av. total cost per farm | 12520 | 6000 - 29895 |
| av. cost per farm per ha planted | 1452 | 480 - 4671 |

(c) Costs excluding fencing

| | | | |
|---|---|---|---|
| 34 all farms | total | 5046 | 620 - 29895 |
| | per ha | 1107 | 218 - 4671 |
| 23 < 5 ha | total | 3124 | 620 - 9259 |
| | per ha | 1122 | 218 - 3086 |
| 11 5 ha + | total | 9065 | 3000 - 29895 |
| | per ha | 1078 | 306 - 4671 |

(d) Costs excluding fencing, split by labour source

| | | | | |
|---|---|---|---|---|
| all farms (34) | per ha home | (10) | 695 | 218 - 1594 |
| | contractors | (24) | 1279 | 306 - 4671 |
| < 5 ha | per ha home | (9) | 735 | 218 - 1594 |
| | contractors | (14) | 1370 | 417 - 3086 |
| 5 ha+ | per ha home | (1) | 333 | 333 |
| | contractors | (10) | 1152 | 306 - 4671 |

Table 8: Farm Woodland Scheme Areas in ha

| Total area of Application/Farm | Avs Area | Avs Plot size | Range |
|---|---|---|---|
| < 5 ha | 3.2 | 2.2 | 0.8 - 4.3 |
| > 5 ha | 12.8 ha | 2.4 | 0.4 - 9.9 |

(Note plots of less than 1 ha form part of another block on different quality land so are shown and calculated separately for different rates of annual payments).

Table 9: Itemised establishment costs £/ha

| | < 5 ha | | > 5 ha | |
|---|---|---|---|---|
| | Avg | Range | Avg | Range |
| Pre-planting | 35 | | 34 | |
| Trees | 271 | 85-538 | 197 | 149-260 |
| Tree Shelters | 597 | 202-1125 | 1219 | 551-1888 |
| Weeding | 51 | 20-83 | 41 | 20-79 |
| Planting by Contractor/ Casual Labour | 374 | 73-657 | 266 | 102-561 |
| Fencing | | | | |
| Materials only | 349 | 100-1077 | 192 | 82-471 |
| Contractor -inclusive cost | 613 | 133-642 | 1099 | 306-1972 |
| Insurance | 2.50 | | 2.50 | |
| Avg Planting Grant | 1060 | 429-1375 | 1061 | 447-1375 |
| Avg Annual Payment | 135 | | 148 | |

Table 10: Prices for Conifers Sold as Standing Timber

| Average Volume per Tree (cu m) | Forestry Commission (1986/87 long-run Prices) (£/cu m) | 1987/88 Standing Sale Prices for Conifers in Scotland (£/cu m) |
|---|---|---|
| 0.2 | 9.2 | 13.0 |
| 0.4 | 16.0 | 17.0 |
| 0.6 | 21.0 | 19.9 |
| 0.8 | 24.7 | 22.2 |
| 1.0 | 26.2 | 24.2 |
| 1.2 | 26.8 | 26.0 |
| 1.4 | 27.2 | 27.6 |

Table 11

Woodland cash flows - all costs and returns calculated per ha.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| land type: | Lowland | WGS planting grant: | 1375 | Mean Cash Flow £/ha: | | NPV | Annuity |
| species: | Sycamore | WGS better land supp: | 200 | FWS | 273 | 2,913 | 185 |
| rotation length: | 50 | FWS planting grant: | 1375 | WGS | 163 | 498 | 32 |
| area: | 2.0 | FWS annual payment: | 190 | No Grant | 131 | -947 | -60 |
| real interest rate: | 6% | years' payment: | 30 | | | | |

| | | | | | ===WGS=== | =========FWS========= | | ========CashFlow======== | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Operation | Cost | Operation | Income | Pl Grant | Pl Grant | Ann Payment | WGS | FWS | No Grant |
| | {Fencing 600 | | | | | | | | | |
| | {Ploughing 25 | | | | | | | | | |
| | {Plants 380 | | | | | | | | | |
| | {Planting 80 | | | | | | | | | |
| 1 | Weeding 70 | 1155 | | | 1,163 | 963 | | 8 | -193 | -1,155 |
| 2 | Beat up/Weed | 180 | | | | | 190 | -180 | 10 | -180 |
| 3 | Weed x 2 | 140 | | | | | 190 | -140 | 50 | -140 |
| 4 | Weed | 40 | | | | | 190 | -40 | 150 | -40 |
| 5 | Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 6 | Maint | 10 | | | 275 | 275 | 190 | 265 | 455 | -10 |
| 7 | Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 8 | Maint/Cleaning | 50 | | | | | 190 | -50 | 140 | -50 |
| 9 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 10 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 11 | Insurance/Maint | 10 | | | 138 | 138 | 190 | 128 | 318 | -10 |
| 12 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 13 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 14 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 15 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 16 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 17 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 18 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 19 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 20 | Insurance/Maint | 10 | Thin | 230 (28 cu m @ £10/cu m) | | | 190 | 220 | 410 | 220 |
| 21 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 22 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 23 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 24 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 25 | Insurance/Maint | 10 | Thin | 286 (28 cu m @ £12/cu m) | | | 190 | 276 | 466 | 276 |
| 26 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 27 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 28 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 29 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 30 | Insurance/Maint | 10 | Thin | 286 (28 cu m @ £12/cu m) | | | 190 | 276 | 466 | 276 |
| 31 | Insurance/Maint | 10 | | | | | 190 | -10 | 180 | -10 |
| 32-34 | Insurance/Maint | 10/year | | | | | 0 | -10 | -10 | -10 |
| 35 | Insurance/Maint | 10 | Thin | 370 (28 cu m @ £15/cu m) | | | 0 | 360 | 360 | 360 |
| 36-39 | Insurance/Maint | 10/year | | | | | 0 | -10 | -10 | -10 |
| 40 | Insurance/Maint | 10 | Thin | 370 (28 cu m @ £15/cu m) | | | 0 | 360 | 360 | 360 |
| 41-49 | Insurance/Maint | 10/year | | | | | 0 | -10 | -10 | -10 |
| 50 | Insurance/Maint | 10 | Clear Fell | 7030 (241 cu m @ £30/cu m) | | | | 7,020 | 7,020 | 7,020 |

Table 12

Woodland cash flows - all costs and returns calculated per ha.

| | | | | | | |
|---|---|---|---|---|---|---|
| land type: | Lowland | WGS planting grant: | 880 | Mean Cash Flow £/ha: | NPV | Annuity |
| species: | Sitka | WGS better land supp: | 200 | FWS 465 | 2,818 | 179 |
| rotation length: | 50 | FWS planting grant: | 505 | WGS 401 | 1,178 | 75 |
| area: | 2.0 | FWS annual payment: | 190 | No Grant 379 | 181 | 11 |
| real interest rate: | 6% | years' payment: | 20 | | | |

| | | | | | | WGS | FWS | | CashFlow | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Operation | | Cost | Operation | Income | Pl Grant | Pl Grant | Ann Payment | WGS | FWS | No Grant |
| | {Fencing | 600 | | | | | | | | | |
| | {Ploughing | 25 | | | | | | | | | |
| | {Plants | 210 | | | | | | | | | |
| | {Planting | 70 | | | | | | | | | |
| 1 | {Weeding | 60 | 965 | | | 816 | 354 | | -149 | -612 | -965 |
| 2 | Beat up/Weed | | 170 | | | | | 190 | -170 | 20 | -170 |
| 3 | Weed x 2 | | 120 | | | | | 190 | -120 | 70 | -120 |
| 4 | Weed | | 60 | | | | | 190 | -60 | 130 | -60 |
| 5 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 6 | Insurance/Maint | | 10 | | | 176 | 101 | 190 | 166 | 281 | -10 |
| 7 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 8 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 9 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 10 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 11 | Insurance/Maint | | 10 | | | 88 | 51 | 190 | 78 | 231 | -10 |
| 12 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 13 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 14 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 15 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 16 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 17 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 18 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 19 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 20 | Insurance/Maint | | 10 | Thin | -50 (70 cu m @ £0.0/cu m) | | | 190 | -60 | 130 | -60 |
| 21-24 | Insurance/Maint | | 10/year | | | | | 190 | -10 | 180 | -10 |
| 25 | Insurance/Maint | | 10 | Thin | 520 (70 cu m @ £8.6/cu m) | | | 0 | 510 | 510 | 510 |
| 26-29 | Insurance/Maint | | 10/year | | | | | 0 | -10 | -10 | -10 |
| 30 | Insurance/Maint | | 10 | Thin | 1000 (70 cu m @ £15.8/cu m) | | | 0 | 990 | 990 | 990 |
| 31-34 | Insurance/Maint | | 10/year | | | | | 0 | -10 | -10 | -10 |
| 35 | Insurance/Maint | | 10 | Thin | 1410 (70 cu m @ £21.9/cu m) | | | 0 | 1,400 | 1,400 | 1,400 |
| 36-39 | Insurance/Maint | | 10/year | | | | | 0 | -10 | -10 | -10 |
| 40 | Insurance/Maint | | 10 | Thin | 1670 (70 cu m @ £25.9/cu m) | | | 0 | 1,660 | 1,660 | 1,660 |
| 41-49 | Insurance/Maint | | 10/year | | | | | 0 | -10 | -10 | -10 |
| 50 | Insurance/Maint | | 10 | Clear Fell | 16180 (634 cu m @ £27.7/cu m) | | | | 16,170 | 16,170 | 16,170 |

Table 13

Woodland cash flows - all costs and returns calculated per ha.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| land type: | Lowland | VGS planting grant: | 880 | Mean Cash Flow £/ha: | | NPV | Annuity |
| species: | Scots Pine | VGS better land supp: | 200 | FWS | 315 | 2,002 | 123 |
| rotation length: | 62 | FWS planting grant: | 585 | VGS | 263 | 362 | 22 |
| area: | 2.0 | FWS annual payment: | 190 | No Grant | 245 | -634 | -39 |
| real interest rate: | 6% | years' payment: | 20 | | | | |

| | | | | | | VGS | FWS | | CashFlow | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Operation | | Cost | Operation | Income | Pl Grant | Pl Grant | Ann Payment | VGS | FWS | No Grant |
| | (Fencing | 600 | | | | | | | | | |
| | (Ploughing | 25 | | | | | | | | | |
| | (Plants | 190 | | | | | | | | | |
| | (Planting | 70 | | | | | | | | | |
| 1 | (Weeding | 60 | 945 | | | 816 | 354 | | -129 | -592 | -945 |
| 2 | Beat up/Weed | | 170 | | | | | 190 | -170 | 20 | -170 |
| 3 | Weed x 2 | | 120 | | | | | 190 | -120 | 70 | -120 |
| 4 | Weed | | 60 | | | | | 190 | -60 | 130 | -60 |
| 5 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 6 | Insurance/Maint | | 10 | | | 176 | 101 | 190 | 166 | 281 | -10 |
| 7 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 8 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 9 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 10 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 11 | Insurance/Maint | | 10 | | | 88 | 51 | 190 | 78 | 231 | -10 |
| 12 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 13 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 14 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 15 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 16 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 17 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 18 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 19 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 20 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 21 | Insurance/Maint | | 10 | | | | | 190 | -10 | 180 | -10 |
| 22 | Insurance/Maint | | 10 | Thin | -50 (49 cu m @ £0.0/cu m) | | | 0 | -60 | -60 | -60 |
| 23-26 | Insurance/Maint | | 10/year | | | | | 0 | -10 | -10 | -10 |
| 27 | Insurance/Maint | | 10 | Thin | 170 (49 cu m @ £4.7/cu m) | | | 0 | 160 | 160 | 160 |
| 28-31 | Insurance/Maint | | 10/year | | | | | 0 | -10 | -10 | -10 |
| 32 | Insurance/Maint | | 10 | Thin | 460 (49 cu m @ £11/cu m) | | | 0 | 450 | 450 | 450 |
| 33-36 | Insurance/Maint | | 10/year | | | | | 0 | -10 | -10 | -10 |
| 37 | Insurance/Maint | | 10 | Thin | 690 (49 cu m @ £16/cu m) | | | 0 | 680 | 680 | 680 |
| 38-41 | Insurance/Maint | | 10/year | | | | | 0 | -10 | -10 | -10 |
| 42 | Insurance/Maint | | 10 | Thin | 920 (49 cu m @ £20.8/cu m) | | | | 910 | 910 | 910 |
| 43-46 | Insurance/Maint | | 10/year | | | | | | -10 | -10 | -10 |
| 47 | Insurance/Maint | | 10 | Thin | 1100 (49 cu m @ £24.7/cu m) | | | | 1,090 | 1,090 | 1,090 |
| 48-51 | Insurance/Maint | | 10/year | | | | | | -10 | -10 | -10 |
| 52 | Insurance/Maint | | 10 | Thin | 1180 (49 cu m @ £26.4/cu m) | | | | 1,170 | 1,170 | 1,170 |
| 53-61 | Insurance/Maint | | 10/year | | | | | | -10 | -10 | -10 |
| 62 | Insurance/Maint | | 10 | Clear Fell | 12600 (499 cu m @ £27.4/cu m) | | | | 12,590 | 12,590 | 12,590 |

REFERENCE

Crabtree J.R., Cumming D. (1989). Farm Woodland Enterprise - Planning, Establishing and Managing Farm Woodlands. SAC.

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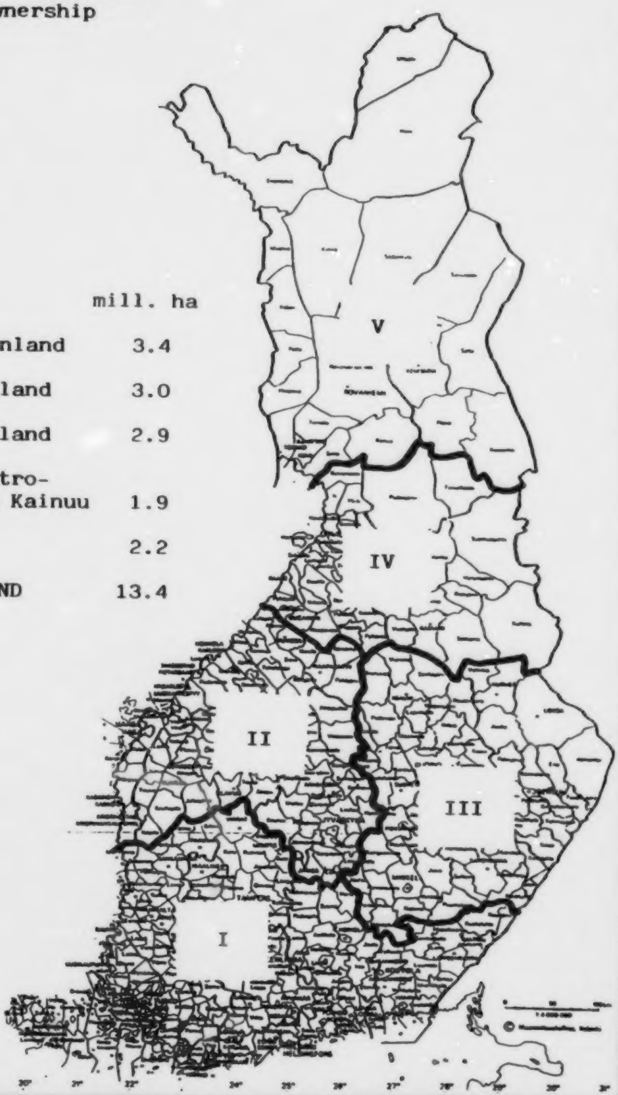
Annex I

## Productive Forest Land Area under Private Ownership

| Region | | mill. ha |
|---|---|---|
| I | Southern Finland | 3.4 |
| II | Western Finland | 3.0 |
| III | Eastern Finland | 2.9 |
| IV | Northern Ostrobothnia and Kainuu | 1.9 |
| V | Lapland | 2.2 |
| | TOTAL FINLAND | 13.4 |



# PROFITABILITY OF FORESTRY IN JAPAN

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## SUMMARY

The market price of wood in our country is largely affected by the price of imported logs occupying 2/3 of wood supply. The decline of the price of logs in recent years has brought about the depreciation of the price of stumpage while the production cost of logs is developing a tendency to increase, because wages or material cost are rising constantly. Therefore, the profitability of forestry decreases every year and it is of urgent necessity for a forestry household to conserve the labor in silvicultural procedure. On the other hand, the national expectation to various functions of a forest such as function for preservation of the environment or the like urges forestry having pursuited profitability to the development of new forest work and the conversion of a management policy.

Keywords: Profitability of forestry, management cost, forest work

## INTRODUCTION

In this paper, following two points are taken up.
(1) The production cost and profitability of forestry in private forest land of our country are analyzed.
(2) The possibility for the development of various forest works and that for the establishment of a new management policy are discussed from the viewpoint of the preservation of the forest environment.

## PRESENT SITUATION OF MANAGEMENT OF PRIVATE FOREST LAND IN JAPAN

The demand of logs in Japan is 92 million-95 million $m^3$ per year for three years from 1985 to 1987 and the production of logs in our country is 31 million $m^3$ corresponding to about 1/3 of the total demand. In 1987, 19.9 million $m^3$ corresponding to 64% of the production of logs in our country was produced from private forest lands.

Next, the present situation of private forest land is considered. According to World Agricultural and Forestry Census 6) in 1980, the total number of forestry households in our country are 2.53 million (excepting a company, shrines and temples, forest under common ownership or the like) and, with respect to the ratio of the number of forestry households by scale on a managing forest area basis, a class of 0.1-below 5 ha is 88.6%, a class of 5-20 ha is 9.5%, a class of 20-50 ha is 1.6%, a class of 50-100 ha is 0.3%, a class of 100-500 ha is 0.1% and a class of 500 ha or more is 0.01% and a small landownership class commands an overwhelming majority. From the viewpoint of the areal ratio to the total forestry area of 6.76 million ha possessed by forestry households, a class of 0.1-5 ha is 33.3%, a class of 5-20 ha is 30.6%, a class of 20-50 ha is 16.0%, a class of 50-100 ha is 6.9%, a class of 100-500 ha is 8.3% and a class of 500 ha or more is 4.9%

In Table 1, the situation of forestry household economy of 1-500 ha classes in 1987 is shown.

Table 1: Summary of Forestry Household Economy
Forestry Household Economy of 1ha~500ha

| Fiscal Year and By Size of Operating Forest Area | Number of family members at beginning of the fiscal year | Operating forest | | | Cultivated area | Cut-over area regeneration-cutting of artificial forest | Area of artificial afforestation | Worked days for forestry operation |
|---|---|---|---|---|---|---|---|---|
| | | Forest area | Area of artificial forest | Ratio of artificial forest | | | | |
| | person | a | a | % | a | a | a | man-day |
| 1981 | 4.8 | 1.591 | 840 | 52.8 | 421 | 3 | 8 | 53.1 |
| 82 | 4.9 | 1.587 | 887 | 55.9 | 449 | 3 | 8 | 48.5 |
| 83 | 4.8 | 1.595 | 907 | 56.9 | 408 | 3 | 7 | 38.9 |
| 84 | 4.9 | 1.573 | 906 | 57.6 | 438 | 5 | 6 | 39.5 |
| 85 | 4.9 | 1.557 | 893 | 57.4 | 441 | 5 | 4 | 37.7 |
| 86 | 4.9 | 1.559 | 899 | 57.7 | 455 | 5 | 4 | 37.1 |
| 87 | 4.8 | 1.543 | 903 | 58.5 | 433 | 3 | 4 | 34.5 |
| *) 1ha~5ha | 4.2 | 227 | 119 | 52.3 | 180 | 7 | 0.4 | 1) 15.0 |
| 5~20 | 4.8 | 888 | 490 | 55.2 | 458 | 2 | 3 | 24.8 |
| 20~50 | 4.9 | 3.205 | 2.056 | 64.1 | 319 | 5 | 14 | 66.9 |
| 50~100 | 4.6 | 6.880 | 3.972 | 57.7 | 299 | 16 | 29 | 102.3 |
| 100~500ha | 4.4 | 17.958 | 10.682 | 59.5 | 318 | 43 | 50 | 205.8 |

Source : Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries, Farm Household Economy Survey, 1987 Fiscal Year
1) estimated value
*) Data of the size 1ha~5ha (1986 Fiscal Year) are left out from average calculations.
Note : Data of the size 1ha~5ha and 5ha~20ha are obtained from the common samples with Farm Household Economy Survey, Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries.

In consideration of the ratio of an artificial forest to the managing forest area of forestry households (hereinbelow referred to as "ratio of artificial forest"), the ratio of artificial forest is 58.5% as the whole of forestry households in 1987 and rises by 0.8 points as compared with the preceding year. From the aspect of a managing forest scale (hereinbelow referred to as "by scale"), a class of 20-50 ha is as highest as 64.1%. Artificial regeneration in Japan was started from about 1960 on a full scale and the ratio of artificial forest of forestry households reached about 60% now, 30 years thereafter, because the area requiring tending work has been accumulated during this period.

On the other hand, the native logs are exposed to the severer competition with imported logs or substitutes, because of the hanging low of the domestic demand of wood and a rising tendency in the exchange rate of the yen and the market price of wood develops a tendency to fall. For example, in Japanese cedar being a representative tree species in the forestation of our country, the market price thereof in 1986 falls by as much as 31% on the basis of 1980 highest in the price of logs (price of logs = price of stumpage + production cost of logs) for these 10 years while the ratio of the production cost of logs to the price of logs shows a rise of 12% 7). This means that the price of stumpage calculated by subtracting the production cost of logs from the price of logs is markedly lowered. In consideration of this tendency at every kind of a tree, the maximum price of stumpage for 10 years from 1977 to 1986 [( ): recording year] is compared with the price of the stumpage in 1986 to obtain such a result that Japanese cedar falls by 43% (to 1980), Japanese cypress by 34% (to 1981), Japanese red and black pine by 56% (to 1979) and Japanese larch by 39% (to 1979). Therefore, it is necessary to conserve the cost of silviculture and that of cutting and carrying in order to increase the shares of forest owners as much as possible and it must be considered to start silviculture from the review of a labor heavy-investment type silvicultural system.

## EXPENSE OF SILVICULTURE BY ITEM OF EXPENDITURE AND MANAGEMENT BALANCE OF FORESTRY BY FOREST MANAGING SCALE

Japanese cedar is taken as an example to investigate the expense of silviculture by an item of expenditure '1986) and the forestry management balance by a forest managing scale (1986, 1987)(1 dollar = 160 yen).

In Table 2, expenses per ha relating to harvesting and silviculture are shown. However, the expenses by forest managing scale are shown only by an average value, because there are no data. Further, only the total values were shown with respect to Japanese cypress, Japanese red and black pine and Japanese larch.

At first, the expenses of harvesting work are investigated 8). Road opening material expenses (stone, wood ,cement or the like), maintenance expenses and direct material expenses of various tools, fuel or the like required from cutting to skidding are 135 thousand yen while personnel expenses such as wages of a field overseer, support clerks or the like, various allowances, workmen's compensation insurance expenses or the like and indirect expenses such as compensation or the like are summed up as social expenses to reach 569 thousand yen in total and the depreciation of machines is 244 thousand yen. If all of felling and bucking, and logging are allotted to a contractor, the expenses thereof become 2.65 million yen centering around personnel expenses. Therefore, the sum total of the expenses required in harvesting work reaches about 3.6 million yen.

From the investigation result of the 1986 fiscal year 9), the ratio of the production cost of logs to the price of logs is 40% in Japanese cedar, 27% in Japanese cypress, 62% in Japanese red and black pine and 58% in Japanese larch. Especially, The Japanese larch increases by as much as 11 points as compared with the preceding year by an increase in the production cost of logs. As mentioned above, since the production cost of logs occupies

Table 2: Costing of Forestry Operations (1986 Fiscal Year)
(Total amount of forestry operations costs from 1 to 50 age)

Unit: 1,000 yen per ha

| Type of cost<br>Cost Centre | Materials | Wages | Social costs | Depreciation | Contr. operations | Owner's own work | Total of cost |
|---|---|---|---|---|---|---|---|
| Japanese cedar | 464.5 | 601.7 | 583.0 | 315.3 | 3,128.6 | 384.1 | 5,477.2 |
| 1 Harvesting | 135.1 |  | 568.9 | 244.1 | 2,650.2 |  | 3,598.3 |
| 2 Regeneration |  |  |  |  |  |  |  |
| • soil prep./ clearing |  | 74.9 | 14.1 | 71.2 | 478.4 | 24.4 | 1,781.7 |
| • planting | 190.7 | 59.1 |  |  |  | 21.2 |  |
| • re-planting | 13.0 | 5.7 |  |  |  | 8.5 |  |
| • brushing and weeding |  | 268.1 |  |  |  | 157.9 |  |
| • starting fertilization | 1.0 | 0.4 |  |  |  | 0.3 |  |
| 3 Cleaning and pruning |  |  |  |  |  |  |  |
| • standing fallen trees |  | 45.8 |  |  |  | 37.7 |  |
| • bine cutting |  | 7.3 |  |  |  | 9.8 |  |
| • pre-commercial thinning |  | 38.8 |  |  |  | 32.4 |  |
| • pruning |  | 71.5 |  |  |  | 48.5 |  |
| 4 Forest improvement |  |  |  |  |  |  |  |
| • drainage |  |  |  |  |  |  |  |
| • fertilization | 8.9 | 1.5 |  |  |  | 1.5 |  |
| 5 Forest protection and administration | 53.7 | 5.2 |  |  |  | 30.2 |  |
| 6 Other costs | 62.1 | 23.4 |  |  |  | 11.7 | 97.2 |
| Japanese cypress | 525.6 | 617.7 | 528.6 | 221.1 | 3,242.7 | 379.1 | 5,514.8 |
| Japanese red and black pine | 292.5 | 236.2 | 323.0 | 136.2 | 1,896.2 | 107.0 | 2,991.1 |
| Japanese larch | 226.5 | 44.5 | 192.1 | 160.8 | 1,723.1 | 105.1 | 2,452.1 |

Source : ① Forestry Agency, Report of Stumpage Market Survey, (F.Y.1986) ② Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries, Farm Household Economy Survey. (F.Y.1986)

Note : All the costs are presented without subtracting direct subsidies.
The subsidies are paid for the works of regeneration, cleaning and pruning except bine cutting and pruning, road building, forest improvement, forest protection and administration.
The amount of subsidies are calculated in each prefecture as follows.
Amount of subsidy = standard unit cost x area of operation x assessed coefficient x rate of subsidy
(assessed coefficient x rate of subsidy = 40~70(%))

about 60% of the price of logs in an inexpensive tree species such as Japanese red and black pine or Japanese larch, the reduction of the expenses of this part becomes a condition for increasing the price part of stumpage (a share of a forest owner).

Next, the expenses relating to silviculture are investigated. In this case, a land rent and interest expenses are not contained in the expenses of silviculture. At first, material expenses reach 330 thousand yen in total and seedling cost occupies as much as 62%. Weeding occupies the greatest part in the sum of employment labor and family work. When the charge of 250 thousand yen in contract work up to 5 years is added as the expenses used in weeding, about 40% of the expenses of silviculture can be regarded as weeding expenses. Further, workmen's compensation insurance and unemployment insurance expenses are summed up as the social costs relating to silviculture but become more than the summed-up costs actually, because this part is also contained in a contract rent for work. Since a social cost part other than this is contained in wages and other management expenses, it is difficult to distinguish said part.

In Table 3, labor investment quantities by work were shown by forest age. However, labor quantity due to contract work is not contained in this table.

Table 3: Input Labor by Kind of Works (1~50 age) Unit: man-days per ha

| 1986 Fiscal Year<br>Item | Total | Age of trees | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1~5 | 6~10 | 11~15 | 16~20 | 21~30 | 31~50 |
| Japanese cedar | 141.9 | 70.3 | 32.5 | 15.0 | 7.5 | 8.8 | 7.8 |
| Soil preparation | 14.8 | 14.8 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| Planting | 12.0 | 12.0 | - | - | - | - | - |
| Fertilization | 0.3 | 0.3 | 0.0 | 0.0 | - | - | 0.0 |
| Re-planting | 1.8 | 1.7 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Weeding | 62.2 | 35.1 | 19.9 | 4.6 | 1.0 | 1.0 | 0.6 |
| Standing fallen trees | 11.1 | 3.1 | 4.7 | 1.9 | 0.5 | 0.7 | 0.2 |
| Bine cutting | 3.1 | 0.5 | 0.9 | 0.5 | 0.5 | 0.4 | 0.3 |
| Pre-commercial thinning | 11.0 | 0.7 | 1.1 | 2.7 | 1.8 | 2.9 | 1.8 |
| Pruning | 16.2 | 0.6 | 4.6 | 4.5 | 2.9 | 2.3 | 1.3 |
| Other | 9.4 | 1.5 | 1.2 | 0.8 | 0.8 | 1.5 | 3.6 |
| Japanese cypress | 128.4 | 62.7 | 28.4 | 12.4 | 7.4 | 10.7 | 8.8 |
| Japanese red and black pine | 48.2 | 23.1 | 5.3 | 6.1 | 4.0 | 3.8 | 5.9 |
| Japanese larch | 21.3 | 12.8 | 0.1 | 0.9 | 2.8 | 2.3 | 2.4 |

Source : Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries, Report of Forestry Household Economy Survey - Forest Management Cost, 1986 Fiscal Year

From this table, it is also found out that the most labor is required in weeding.

Next, in Table 4, the forestry management balances of 1986 and 1987 in Japan were shown. At first, forestry gross income per forestry household in 1987 increased by about 18% as compared with that in 1986. Especially, the increase of a log production department is marked. This increase is caused by a sudden rise in the price of wood centering around Japanese cypress during a period from June to September with an increase in the construction numbers of

Table 4: Balance of Forestry Management (1) - Forestry gross income
Forest Household Economy of 1ha~500ha

Unit: 1.000 yen

| | | Forestry gross income | | | | | | |
|---|---|---|---|---|---|---|---|---|
| and By Size of Operating Forest Area | | Total | Cash | Silviculture | Production of logs | Production of fuelwood and charcoals | Production of "Shiitake" and mushrooms | Others |
| 1981 | | 579.7 | 522.3 | 219.0 | 139.7 | 17.5 | 160.1 | 43.4 |
| 82 | | 570.7 | 542.6 | 201.5 | 134.9 | 14.8 | 188.8 | 30.7 |
| 83 | | 531.4 | 513.1 | 163.7 | 132.8 | 21.0 | 179.6 | 34.3 |
| 84 | | 515.2 | 476.2 | 151.5 | 140.4 | 20.5 | 160.4 | 42.4 |
| 85 | | 534.9 | 520.5 | 190.3 | 137.9 | 18.0 | 154.4 | 34.3 |
| 86 | | 502.8 | 489.6 | 181.5 | 118.3 | 15.5 | 154.5 | 33.0 |
| 87 | | 591.8 | 575.0 | 174.6 | 170.3 | 14.6 | 194.4 | 37.9 |
| *) 1~5ha | 86 | 112.9 | 99.1 | 14.4 | 7.4 | 11.3 | 60.8 | 19.0 |
| 5~20 | 86 | 307.7 | 291.8 | 101.5 | 32.1 | 14.8 | 144.5 | 14.8 |
| | 87 | 371.4 | 358.9 | 96.1 | 43.7 | 14.7 | 197.9 | 19.0 |
| 20~50 | 86 | 941.5 | 940.6 | 364.6 | 232.4 | 18.4 | 209.6 | 116.5 |
| | 87 | 1.054.7 | 1.025.0 | 315.8 | 469.4 | 12.9 | 177.1 | 79.5 |
| 50~100 | 86 | 1.572.9 | 1.548.7 | 650.3 | 618.5 | 25.2 | 182.0 | 96.9 |
| | 87 | 2.227.8 | 2.210.8 | 973.4 | 838.4 | 21.1 | 192.6 | 202.3 |
| 100~500ha | 86 | 7.297.3 | 7.264.3 | 2.830.8 | 4.081.5 | 9.4 | 148.9 | 226.7 |
| | 87 | 7.673.9 | 7.650.6 | 2.489.6 | 4.459.3 | 12.5 | 147.2 | 565.3 |

Source : Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries, Report of Forestry Household Economy Survey, 1987 Fiscal Year
*) Data of the size 1ha~5ha are left out from average calculations.

Balance of Forestry Management (2) - Forestry expenditure
Forest Household Economy of 1ha~500ha

Unit: 1.000 yen

| | | Forestry expenditure | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| and By Size of Operating Forest Area | | Total | Cash | 1) Paid for employees | Material wood cost | 2) Materials cost | Contract rent for work | 3) Others | Depreciation |
| 1981 | | 250.3 | 220.1 | 64.9 | 13.1 | 38.6 | 52.9 | 80.8 | 29.4 |
| 82 | | 279.2 | 247.0 | 56.0 | 13.9 | 44.0 | 78.9 | 86.4 | 31.8 |
| 83 | | 238.4 | 207.8 | 49.3 | 13.6 | 36.4 | 60.8 | 78.3 | 30.6 |
| 84 | | 238.3 | 205.3 | 46.4 | 8.7 | 35.7 | 59.6 | 87.9 | 32.5 |
| 85 | | 251.6 | 215.4 | 39.5 | 21.6 | 32.5 | 72.9 | 85.1 | 35.9 |
| 86 | | 232.5 | 195.9 | 36.7 | 16.3 | 36.5 | 55.9 | 87.1 | 38.4 |
| 87 | | 251.0 | 209.7 | 36.8 | 14.0 | 42.2 | 63.2 | 94.8 | 40.8 |
| *) 1~5ha | 86 | 55.4 | ? | 4.4 | 7.6 | 15.4 | 2.5 | 25.5 | 12.5 |
| 5~20 | 86 | 133.7 | 103.1 | 7.2 | 16.2 | 27.5 | 18.9 | 63.9 | 30.6 |
| | 87 | 149.8 | 114.1 | 8.2 | 13.8 | 35.8 | 22.1 | 69.9 | 35.7 |
| 20~50 | 86 | 410.4 | 358.6 | 88.3 | 18.0 | 66.3 | 104.0 | 133.8 | 50.5 |
| | 87 | 446.1 | 390.6 | 84.8 | 17.2 | 61.4 | 125.8 | 156.9 | 53.1 |
| 50~100 | 86 | 791.6 | 711.8 | 207.0 | 7.6 | 80.8 | 257.2 | 239.0 | 79.7 |
| | 87 | 882.7 | 804.5 | 229.6 | 3.5 | 80.0 | 310.2 | 259.4 | 74.9 |
| 100~500ha | 86 | 4.176.0 | 3.978.2 | 1.252.5 | 37.8 | 221.4 | 1.782.0 | 882.3 | 195.7 |
| | 87 | 3.994.2 | 3.796.6 | 1.147.3 | 17.5 | 200.5 | 1.814.7 | 814.2 | 193.3 |

1) Including workmen's compensation insurance.
2) Materials cost consists of Planting stock and fungi cost, Fertilizers and manures cost, Forestry chemicals cost and Miscellaneous materials cost.
3) Others include charges and fees.
*) Data of the size 1ha~5ha are left out from average calculations.

houses. Further, the gross income of a mushroom production department was increased by 26% as compared with that in 1986, because of an increase in the production of fresh Shiitake and other cultured mushrooms. Next, from a viewpoint by class, the silvicultural production (sale on stumpage) in 1987 increases by 50% in a class of 50-100 ha as compared with the preceding year but slightly decreases in other classes. On the other hand, the production of logs increases in all of classes as compared with the preceding year on the basis of the previously described cause and, especially, a class of 20-50 ha becomes twofold. Further, the production of mushroom increases by 37% in a class of 5-20 ha as compared with the preceding year but too much change is not found out in other classes. In this department, the ratio to forestry gross income is high on the whole as classes become small-scaled and 54% in a class of 1-5 ha (materials in 1986), 53% in a class of 5-20 ha, 17% in a class of 20-50 ha, 9% in a class of 50-100 ha and 2% in a class of 100-500 ha. That is, the classes of 20 ha or less occupy the half or more of forestry gross income in the amount of production of mushroom centering around Shiitake.

Next, forestry expenditures per forestry household in 1987 increased by 8% as compared with the preceding year and, at every items of expenditure, material expenses rise by 16%, contract charge by 13% and depreciation by 12%. This rise reflects the growth of the production of logs caused by a temporary rise in the price of wood. In consideration by class, the class of 100-500 ha decreased by about 4% as compared with the preceding year but other classes increased by 9-12%. From the viewpoint of the ratio of the wage part, wherein employment wages and contract charge were combined, to the whole of forest managing expenses, the class of 1-5 ha is 12% (materials in 1986), the class of 5-20 ha is 20%, the class of 20-50 ha is 47%, the class of 50-100 ha is 61% and the class of 100-500 ha is 745 and it is cleared that the ratio of the wage part becomes high as a scale becomes larger.

On the other hand, the forestry income calculated by subtracting forestry managing expenses from forestry gross income largely increases in all of classes as compared with the preceding year, because the gross income increased so as to exceed an increase in managing expenses.

## PROFITABILITY OF JAPANESE FORESTRY

The price of domestic logs in our country is showing a tendency to fall by the hanging low of demand for wood, the stable import of inexpensive foreign logs, the advance of a substitute for wood and a sudden rise in the exchange rate of the yen. This tendency was mainly brought about by a lowering of the price of stumpage 4).

Herein, a change in an inner earning rate is considered when the final cutting age of Japanese cedar was set to 45 years. In Table 5, values at every 5 years from 1961 to 1986 are shown 1). The inner earning rate of 8.1% in 1961 decreases steadily thereafter to fall to as low as 2.0% in 1986. This value means that reforestation is impossible even if the forestation funds being the lending funds of Agriculture, Forestry and Fisheries Finance Corporation whose annual interest is as lowest as 3.5% are used. However, since this value is calculated without containing a forestation subsidy, an inner earning rate slightly rises on the assumption that about 40% of silvicultural work expenses excepting bine cutting and pruning is promoted. In a certain instance, a rise in the inner earning rate of about 1-2% is said to be estimated by containing the subsidy 2),10). However, when the inner earning rate is calculated without including the subsidy in Japanese red and black pine or Japanese larch in the price of stumpage and a final cutting age is set to 50 years, Japanese red and black pine is 0.9% and Japanese larch is 1.3% in 1986 and, therefore, it may be said that the inner earning rate can not calculated if the subsidy is subtracted.

Table 5: Balance of Management Investment and Inner Earning Rate
(Japanese cedar: final cutting age 45, final cutting volume 300m³/ha, national average)

| Fiscal Year | Forest management cost by age of trees (1,000 yen/ha) | | | | | | Stumpage price (1,000 yen/m³) | Final income (1,000 yen/ha) | 1) Inner earning rate (%) |
|---|---|---|---|---|---|---|---|---|---|
| | 1~5age | 6~10 | 11~20 | 21~30 | 31~45age | Total | | | |
| 1961 | 72 | 21 | 19 | 11 | 10 | 133 | 9.1 | 2.724 | 8.1 |
| 66 | 143 | 41 | 38 | 21 | 21 | 265 | 9.8 | 2.927 | 6.5 |
| 71 | 274 | 79 | 86 | 38 | 42 | 519 | 12.0 | 3.612 | 5.3 |
| 76 | 715 | 187 | 182 | 104 | 122 | 1.309 | 19.6 | 5.874 | 4.2 |
| 81 | 1.184 | 414 | 319 | 153 | 133 | 2.203 | 20.2 | 6.064 | 2.8 |
| 86 | 1.069 | 399 | 264 | 123 | 125 | 1.981 | 14.1 | 4.243 | 2.0 |

Source : Minoru Kumasaki, Ringyo Keiei Tokuhon (Forestry Management Reader), p.63, 1989

1) $$\frac{R}{(1+P)^{45}} = \sum_{n=1}^{45} \frac{Cn}{(1+p)^n}$$

P : inner earning rate
R : final income
Cn: n-year management cost after planting

As mentioned above, when the inner earning rate is calculated from the present price of stumpage and a silvicultural level, Japanese cedar being the representative tree species of forestation is 2% and Japanese cypress is as highest as 2.8% (in the case of a final cutting age of 50 years). Therefore, a forestry household is confronted with such a situation that it is advantageous to buy financial goods yielding a high-rate return in place of forestation investment. Not a few forestry households has stopped own forestation investment by making a contract of proceeds-sharing afforestation with Forest Development Corporation or prefecture and withdrawn substantially from the management of forestry to retract to the ownership of forest.

## PROFITABILITY AND LABOR SAVING OF FORESTRY

The profitability of forestry is affected by the difference between the price of stumpage and the expenses of silviculture assuming the sale of stumpage giving a log manufacturer and forest cooperative a contract for a harvested part. Therefore, the reduction in silvicultural expenses is related to a rise in payability to a forestry household. As stated above, weeding is most expensive among silvicultural works. In the case of Japanese cedar, about 100 persons per ha have been charged in the total of family, employment and contract labor quantities during 50 years and, especially, about 70 persons have been charged collectively for 5 years from planting. The labor saving of this part must be considered at first.

In groping procedure for achieving the cost reduction of silvicultural works, the labor saving of planting or pruning work is attained but, since the greater part of a silvicultural process is performed in forest land having steep topography in our country, it is difficult to enhance silvicultural efficiency to a large extent by mechanical force.

Under this situation, a forestry household is ready to attain to conserve expenses by reducing labor investment quantity. That is, when the average labor investment quantity of the forestry household belonging to the class of 5-500 ha in 1981 is compared with that in 1987 according to the Survey of Forestry Household Economy, 60 persons per forestry household per year are reduced to 43 persons. With due regard to this constitution, contract labor quantity of about 8 persons is not almost changed but family and employment labor quantities are reduced. As mentioned above, a forestry household ready to attain to conserve expenses by reducing the employment labor quantity is increasing and this tendency shows that "omission forestry" is ready to spread.

In this severe economical environment, it is not permitted that labor is invested in silvicultural works aimlessly as is conventional. From now on, a production target must be cleared, and the silvicultural process and the distribution of labor suitable for said target must be investigated. That is, it is necessary to clearly distinguish a part possible in labor saving from a part impossible in labor saving. Further, it is necessary to reconsider the creation of even-aged uniform forest and a short rotation and clearly cutting system from the viewpoint of profitability or preservation of the environment. Various forest types and various forest works will be requested for the future. In actual, advanced forest managers are managing to take the natural change of a forest ecological system in a silvicultural process to achieve labor saving as much as possible 3).

Further, as a measure for the labor saving in the silvicultural or cutting and carrying process, the introduction of various forestry machines is actively performed but many technical and political subjects to be solved in order to attain the mechanization of forestry are still left in our country by the aforementioned topographical problem or the factor of small-scale dispersibility in the ownership of a forest. The enhancement of working efficiency by mechanization in the cutting and carrying process can be expected as compared with the silvicultural process but, in introducing machines, it is necessary to sufficiently consider the natural conditions or social and economical conditions of a region. If a clear cutting area becomes large or a cutting method becomes rough because the machines are introduced without considering the above mentioned conditions, various problems will be brought about in the aspect of the preservation of the environment even if productive capacity is temporarily enhanced.

The development of forestry machines is necessary in order not only to compensate the shortage of labor but also to enhance profitability but, previous to this, it is important to promote conditional arrangement such as the systematization of the production, distribution and processing of wood, the investigation on problems of workers, the improvement in a forestry road system and the zoning of forest by function or the like. Especially, with respect to the zoning of the forest by function, if a forest equipped with a condition capable of pursuiting profit through the introduction of a large-scale machine or a forest whose maintenance must be considered at first can be distinguished, an object to be achieved in cost reduction becomes clear and efficient technical development will become possible 5).

## CONCLUSION

The profitability of the forestry in our country is still on a low level presently as mentioned above. The inner earning rate is on such a level that reforestation is actually impossible even in Japanese cedar if there is no subsidy and, as for Japanese red and black pine or Japanese larch, the calculation of an inner earning rate is impossible in many cases if the subsidy is omitted. Therefore, at first thought, silvicultural management will be said to be not formed in the greater part of regions in our country under the present situation. However, this consideration is adapted to such a case that artificial planting is applied to cut-over land from now and a separate way of thinking will be adapted to almost all of artificial forests in a tending process presently. That is, it can be said that the artificial forest reaching 10 million ha in our country have become considerably substantial from the aspect of resources by the political support to the tending work and, to the greater part of forestry households, the silvicultural investment before many years is not considered as the expenses for production and the difference between the production amount at the present point of time and invested expenses, that is, the magnitude of gross income of the year concerned is put in question. Further, a final cutting age shows a tendency to extend by the hanging low of the price of logs. In addition, excepting a special case, it can not be executed that an even-aged uniform forest is created over a large area as performed heretofore to be cut at short rotation, for the future from the viewpoint of profitability, the social and economical conditions surrounding forestry and preservation of the environment. From the foregoing, it is considered that a conditions for converting the conception of a conventional theory of interest rate on soil to that of a theory of interest rate in forest is ready to be gradually set.

In order to preserve the forest environment to make sustained timber yield possible, an important subject to be investigated for the future of Japanese forestry will reside in that rational low cost tending work omitting wastefulness and certainly executing necessary tending work is realized and the present Forest Planning System or various tax systems are reviewed under the way of thinking according to the theory of interest rate in forest on the basis of the replenishment of forest resources.

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# THE DEVELOPMENT OF COOPERATION IN THE FRENCH PRIVATE FORETS

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## RESUME

Les différentes statistiques du ministère de l'agriculture et de la forêt dénombrent environ 3 600 000 propriétaires privés pour une surface de près de 10 millions d'hectares.

Afin de remédier à ce morcellement, les pouvoirs publics et les organisations professionnelles ont mis en place, depuis une cinquantaine d'années, une politique de regroupement des propriétés ou de leur gestion.

Son analysées les différentes formules de regroupement :

- Les **regroupement forestiers** permettent de regrouper des propriétés morcelées et d'éviter le démembrement d'une propriété familiale ; la transformation de droits de propriété en parts de société constitue un frein psychologique pour le développement de ces groupements.

- Les **associations syndicales** sont bien adaptées à la réalisation de projets d'investissement en commun (route, reboisement).

- La vente de produits forestiers est l'activité principale des **groupements de services.**

Ainsi, à la diversité des forêts privées, une gamme de dispositions législatives apporte des éléments de réponse variés où chacun des propriétaires peut trouver une solution correspondant le mieux à son cas personnel.

Mots clés : forêt privée, politique forestière, groupements, coopératives.

The various statistical tables emanating from the Ministry of Agriculture and Forest show that there are approximately 3 600 000 private estates covering an area of close to 10 million hectares.

Moreover, the physical parcelling adds to the juridical division.

This extreme breaking up of the estates is due to :

- the partitioning generation after generation since the time of the Napoleon Code and its egalitarian inheritance code ;
- the clearings, which resulted in the forest being relegated to the hilliest grounds ;
- the afforestations, which increased in consequence of intensified agriculturing and rural depopulation.

For some fifty years, owing to the common interest presented by the forest, the authorities and the professional organizations started a policy of estate grouping, or estate management grouping.

## THE PRIVATE FOREST

In France the private forest represents about three quarters of both the wooded areas and the biological yield and two thirds of both the growing stocks and marketed cuttings.

### Structure of the forests

The division of the private forest obviously is to be considered in a relative way. There are more than 50 000 owners of more than 25 ha which amount to 4.3 million ha. This is as much as the total forest owned by the State and the local communities in metropolitan France, a property which is run by the National Forest Office ("Office national des forêts").

In contrast, more than three million owners share 2.4 million ha.

The average area amounts to 2.6 ha with wide regional disparities, the division being especially high in mountain regions : Vosges, Alps, Central Massif and Pyrenees.

Units 1 000 estates, 1 000 hectares :

| Owners | less than 4 ha | from 4 to 25 ha | from 25 to 100 ha | 100 ha and more |
|---|---|---|---|---|
| -Owner number | 3 271 000 | 355 000 | 42 000 | 9 300 |
| **% of the total** | **89** | **10** | **1** | - |
| -Owned surface (ha) | 2 462 000 | 2 963 000 | 1 905 000 | 2 410 000 |
| **% of the total** | **25** | **30** | **20** | **25** |

Source : Ministry of agriculture and forest, SCEES (ESSES, 1976-1983).

For forest management and exploitation, this division is increased by a scattering of the parcels within the estates : the number of the continuous wooded parcels all in one block is higher than 10 million.

| Continuous wooded parcels | less than 1 ha | from 1 to 4 ha | from 4 to 25 ha | 25 ha and more |
|---|---|---|---|---|
| -Number | 8 692 000 | 1 215 000 | 275 500 | 36 600 |
| -Area (ha) | 2 491 000 | 2 203 000 | 2 315 000 | 2 728 000 |

Source : Ministry of Agriculture and Forest, SCEES (ESSES, 1976-1983).

Standard models of stands (% of the area)

| | |
|---|---|
| - High forest | 48 % (incl. 31 % with prevailing softwood) |
| - Mixed high forest and coppice | 33 % |
| - Simple coppice | 19 % |

Source : National forest inventory.

## The owners

According to an estimate made by F. LEVEQUE (1986) one household out of five owns wooded land. This shows how common forest ownership is in French patrimony.

The average outline of the owner of a forest more than 1 ha in area is clearly distinct from the French population :

- mean age : 58 years,

- 70 % of the owners are either farmers (40 %) or retired persons (30 %) ;

- 82 % live in villages or towns of less than 5 000 inhabitants ;

- 86 % also own agricultural land.

On the basis of statistical data available for more than half of the "departments" D. NORMANDIN (1987) analyzed the various types of forest estates and distinguished :

- the large hardwood estates of flat open country, where patrimonial management prevails (Burgundy and Centre Regions) ;

- the large softwood estates owned by groups and associations, where the stress is put on the investment-forest (northeastern part of France) ;

- the large softwood estates of forest growers who exercise a very intensive management (southwestern part of France) ;

- the very small mountain softwood estate (Vosges, Central Massif and northern Alps) ;

- the small divided estate which is difficult of access (Central Massif, Alps) ;

- the small hardwood estate owned by farmers who exercise a landscape management (South and Pyrenees Regions) ;

- the small estate owned by town-dwellers (Limousin).

The very large diversity of forest owners, together with the variability of both the ecological conditions and the plantations dictate systems of forest development that take each owner's constraints and motivation into account.

## Organisation of the private forest

The 1963 law of Minister PISANI for "the improvement of both production and land structure of the French forests" states that each owner must "carry out the afforestation, the development and the maintenance of his forest in order to ensure its profitability in compliance with the rules of a wise economic management".

This law institutes a systems of professional discipline in which the State hands over the prerogatives of public authority to public institutions managed by professional forest growers : the regional centres of forestry ownership ("Centre régional de la propriété forestière : CRPF).

The CRPF are run by a board composed of elected forest owners ; it is, thus, a professional organism, but it is submitted to a double tutelage :

- a financial tutelage through a financial Controller (most returns are of fiscal origin : land-tax, national forestry fund tax) ;

- a technical tutelage, through a "Government Commissioner" who generally is the director of the regional forestry administration.

The law has given the CRPFs three main goals :

- To prepare ethe regional production orientations and approve the simple operation plans ; these plans are drawn up for continuous forests larger than 25 ha in one block and, under date of Dec. 31, 1988, concern close to 18 000 forests representing 2.3 million ha ;

- To popularize the forestry techniques ;

- To develop forestry groups and co-operation between owners.

As means of grouping, the administration, the CRPF and the syndical associations of forest growers-owners preferentially used :

- Forestry groups, which result in land-estate grouping ;

- Syndical associations, which are flexible means well adapted to investing operations ;

- Service groups, which allow both management and works.

## THE FORESTRY GROUPS

("Groupements forestiers" GF)

Since the national forestry fund was created in 1946 (a fund provided for by a tax on forestry and saw-mill exploitation products), the afforestation was often carried out in a scattered way. In 1954, 70 % of the areas were afforested with a mean surface of 1.80 ha. Attention was more and more often claimed on the disadvantages of this situation from the management, exploitation and rural development standpoints. Forestry grouping derived from this need to improved organizations. The statement of motives of the 1954 ordinance that create the forestry groups, specifies the stakes :

"Of all rural properties the forest is that which require the greatest constancy of views. It is a cultivation with a long-dated harvest. Moreover, as this cultivation is extensive, it must cover a wider area than agricultural estates in order to receive the essential field equipment and give continued income".

Two goals have been fixed by the legislator :

- to permit the constitution of forest management units endowed with the best economic and financial characteristics ;

- To propose a juridical structure allowing the property to be made over while preserving its unity.

A forestry group is an "association of individuals", which new members cannot join without the agreement of the former partners. The aim of this society is strictly limited to forestry or pastoral activities (a such group can include in its real estate up to 30 % pastoral fields, these being required for the cantonment of grazing).

The partners do not hold title-deeds and their shares in the profit (or loss) are determined proportionally to their holding in the registered capital ; each group is governed by statutes which must always be drafted by a lawyer. However, this drafting is facilitated by some models made available by the authorities.

An attractive taxation system is applied provided that the statutes have been approved by the Ministry of Agriculture and Forest ; the constituting act is assigned a fixed registration fee.

In order to promote their creation the forestry groups are given priority in granting from state and national forestry fund.

In almost all cases the groups are constituted by unanimous consent of the partners ; exceptionnally the lax allows a majority of owners to constraint a minority hostile to the project, either with the aim of putting an end to parcenary or in an afforestation district (a zone where afforestation has been declared compulsory).

The groups can be classified into several categories according to their purpose :

- "**Afforestation**" GF., composed of owners of adjoining estates and aiming at afforesting the divided ground ;

- "**Investment**" GF., composed of persons wishing to invest funds in forest estates ;

- "**Conservation**" GF., constituted in order to preserve the single management of a forest : they are family groups which substituted for a joint possession or prevented forest dismemberment.

Statistical investigations of the years 1976-83 show that there are about 3000 forestry groups, representing an area of 480 000 ha. Most of them are family groups ; the groups constituted from divided grounds have not been as successful owing to the fact that owners are reluctant to exchange their title-deeds for interest shares and owing to difficult estimating of each contribution value.

## SYNDICAL ASSOCIATIONS

("Associations syndicales, AS")

Since the beginning of the 19th century, the owners felt the need of grouping in order to facilitate works of common interest. Owing to the difficulties encountered the authorities gave these groupings a legal framework. This was the purpose of the law of June 21, 1865, concerning the syndical associations.

Article 1 of this law specifies which works may be the object of a syndical association :

- Defence against the sea, rivers and streams, the fires in forests, wooded or bare moors, the avalanches, the stone and block falls, the land-slides, etc,

- Cleaning of canals and rivers,

- Draining of marshy grounds and irrigation,

- Cart-tracks,

- Any other agricultural improvement of collective interest, notably afforestation.

The law distinguishes :

- Free associations constituted without the intervention of the authorities ; the unanimous consent of the partners must be given in writing ;

- Authorized associations initiated either by the authorities, or by a free association wishing to be transformed.

The project is submitted to a public inquiry that must reach all owners of the concerned zone ; failing answer, the owner is assumed to agree. For the project to be accepted, the agreement of half the owners possessing the two thirds of the grounds, or the agreement of the two thirds of the owners possessing half the grounds must be obtained.

If authorized, the association is a public organism, which collects taxes from all owners, in the manner of direct taxes ; theses taxes provide for the undertaken works, such as cart-tracks, afforestation, etc. ; These taxes are determined in proportion to the benefit found in these works by each owner.

The association creates duties and charges, but does not interfere with ownership.

As concerns the forest, these arrangements permitted works such as :

- Defence against fire in the southern part of France,

- Cart-tracks, also afforestation, in mountainous areas, where properties are especially divided.

These works being of general interest are given priority to receive grants from the state or the national forestry fund.

Opening up of tracks is a preliminary to a concerted forest management involving all owners.

As an extension of these actions the law of December 4, 1985 for improved forest management created syndical associations of forestry management, which can carry out afforestation, silviculture, equipment, exploitation and marketing of forest products. It is still too early to analyze the results of these new legislative arrangements.

## SERVICE GROUPS

("Groupements de service, GS")

The service groups are based on the sharing of both staff and equipment which are placed at each owner's disposal.

The activities of these groups concern :

- Purchasing of seedlings, fertilizers, tools, etc...,
- Management : working out of simple plans of operations, tree marking, etc...,
- Equipment, plantation works, etc...,
- Selling of standing or felled timber,
- Development of intensive techniques.

The service groups are constituted in various juridical forms in compliance with the owners' wishes :

- Non-profit-making association (law of July 1, 1901) : "Two or more persons share, in a permanent way, their knowledges or activity, with a purpose other than profit sharing" ;
- The professional syndical association (law of March 21, 1884) which works for the study and the defence of its members'economic, industrial, commercial and agricultural interests ;
- The agricultural co-operative (ordinance of September 26, 1967), the objective of which is "the shared use by farmers of all approprriate means facilitating or developing their economic activity, improving or increasing the results of this activity" ;
- The collective-interest agricultural association (decree of August 5, 1961) which reaches farther than the agricultural co-operative : "To create or run fittings and equipments or secure services in the interest either of the farmers of a determined rural region or, more generally, of the inhabitants of the region without professional discrimination".

The two last systems are more constraining, but they present larger intervention possibilities.

In 1985 there were 90 groups (more than half of them being co-operatives) concerning 19 000 members for a forest area of 980 000 ha (P. DUBOIS and D. NORMANDIN).

Part of these groups received starting grants from the national forestry fund, partly covering the expenses for the technician, administrative and commercial staff, the working staff being excluded :

- 80 % of the expenses of the first year,
- 60 % of the second year,
- 40 % of the third year,
- 25 % of the fourth and fifth years.

The main activity is marketing : in 1988, 4 millions de $m^3$ have been marketed, of which 58 % felled wood ; these groups are especially developed in the Southwest and the Centre Regions.

## CONCLUSIONS

The following table summarizes the advantages and disadvantages of the various proposed systems :

| System | Main purpose | Advantages | Disadvantages |
|---|---|---|---|
| Forestry group | -Grouping divided properties<br>-Avoiding family property dismemberment. | -Wholly common management | -The system is heavy<br>-The transformation of property rights into company shares constitutes a psychological restraint |
| Syndical association | Grouping of plots in view of a common investing project | -Flexible system, appropriate notably to roading. | -Running authorized associations is comparatively heavy |
| Service groups | Sharing of technical and staff means | -Groups appropriate to selling forest products | -Management costs comparatively high for small properties. |

It is obvious that forestry groups and syndical associations concern projects of a forest massif size ; the service groups concern another size range : part of a "district", a "department", or even a region.

Thus, the diversity of private forests is matched by a whole range of legal arrangements among which each owner can find the system best adapted to his own case.

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# PROFITABILITY OF PRIVATE FORESTRY IN FINLAND

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## SUMMARY

Profitability of private forestry in Finland in 1986-1988 is determined according to the standards defined by the IUFRO Project Group (P. 3.04-00). Because book-keeping data on individual wood-lots are not available, the aggregate regional data have been used.

Profitability varies greatly by region. In southern Finland the net income per hectare was FIM 524, while in Lapland only FIM 63 was received. In southern Finland the net income per cubic metre was FIM 113 in comparison with FIM 46 in Lapland. The results are largely explained by the varying growing potential of the forests; under favourable growing conditions in southern Finland well-stocked forests grow at a rate of 5.9 $m^3$/ha/year, while in the harsh climate of Lapland poorly-stocked forests grow only at a rate of 1.3 $m^3$/ha/year.

Net incomes are on average 69 % of the gross income from forestry. Taking into account farm forest owners' other income sources, the forest income, including work income, corresponds to 15 to 20 % of the total net earnings of an average farm forest owner. In the households of non-farm forest owners the role of forests as an income source is even less significant. Individual and annual variations are, however, rather large.

Keywords: income, earnings, costs, subsidies

## INTRODUCTION

The aim of the paper is to assess the profitability of private forestry in Finland, using the calculation framework set up by the IUFRO Project Group (P. 3.04-00) for the measurement and comparison of the profitability of private forestry on an international basis. Because comprehensive book-keeping records on individual wood-lots in Finland were not available, the profitability analysis on private forestry was carried out by using aggregate regional data. Consequently, the profitability indicators of Finnish private forestry can only be given in terms of regional means, which greatly restricts the possibilities of drawing conclusions from the results. Inter alia, nothing can be said about the profitability variations within different size groups of private wood-lots.

There are numerous reasons for not setting up a comprehensive book-keeping system of private forestry in Finland. First, in many European countries the forest tax system has required regular recording of inputs and outputs of forestry operations to determine taxable net income of a forestry enterprise. This has, however, not been a necessity in Finland, where a forest owner is taxed annually on the basis of the average growth of forests in the region and the average regional costs of forest management.

Second, the share of forest management costs of the gross income earned from the forests has traditionally been relatively low, at least in the southern parts of the country. Up to the present time the forest owners' willingness and ability to carry out forestry operations on their own initiative has relieved cost pressures. The availability of Government subsidies and grants for different forestry improvement operations has also played an important role in reducing the management costs paid by private forest owners.

Due to changes in the forest ownership structure in recent years forest management costs have, however, increased in real terms, especially in the 1980s. When in the 1960s farmers owned more than 90 % of the private forests, at present their share is down to 60 %. The increasing number of non-farmer forest owners means that a landowner can contribute to the management of his wood-lot less frequently; he either lacks the professional skills required or his wood-lot is too far from his present place of residence. More and more often the professional services required in timber sales, silvicultural works and logging are bought from the local Forest Management Association. Consequently, the cost-consciousness of private forest owners has increased and they have started to pay more attention to cost escalation in forestry.

Although the book-keeping of a wood-lot is not yet a well-established routine among forest owners, profit accounting of forest holdings has long been one of the priority areas in the research conducted under the discipline Business Economics of Forestry in Finland.

Earlier studies (e.g. HAGFORS, 1929 and KELTIKANGAS, V., 1938, 1969) concentrated on developing the necessary theory. Based on empirical data the net revenues of the Finnish farm forests have been studied by PIH[illegible]941, 1957) and SAARI (1929). Other persons (SAARI, 1938, RU[illegible]ERG, 1959, SEVOLA, 1983) have analysed the results of industrial and state-owned forests.

## FOREST RESOURCES PROFILE

The productive forest area in Finland is about 20 million hectares. Productive forest is defined as forest capable of producing at least 1.0 $m^3$ per hectare per year on an average during a 100-year period. Close to two thirds of the forests is owned by private persons. Out of the remaining area, 24 % is owned by the State, 9 % by companies and 4 % by others.

For the profitability analysis the productive forest area in Finland was divided into five geographical regions (I-V), the borders of which are shown in Annex 1. The geographical division is largely based on the growing potential of forests in the different parts of the country.

At present the growing stock on private productive forest land is estimated at 1.2 billion $m^3$ or 70 % of the total growing stock in Finland. Pine (Pinus silvestris) and spruce (Picea abies) make up about 80 % of the growing stock, the rest comprising non-coniferous species, predominantly birch. In the northern parts of the country the forests are dominated by pine, the share of which is 55 % of the regional growing stock. In the southern parts the coniferous growing stock volume is fairly equally distributed between pine and spruce, accounting for 37 % and 44 %, respectively.

Although private forests cover 63 % of the productive forest area, their share of the total growth of the forests is about 75 %. This indicates that the private forests are situated in areas with more favorable growing conditions, as compared with areas managed by the forest product companies and the State. Particularly, this is the case in southern Finland, where the mean volume per hectare in private forests is 107 $m^3$/ha, compared with 78 $m^3$/ha in company forests and 83 $m^3$/ha in State forests (Table 1). In northern Finland the mean volume of the growing stock is in the range of 51 to 60 $m^3$/ha, which means that in the northern parts of the country the growing potential of forests does not markedly vary by type of ownership. However, in southern Finland the mean volume per hectare (101 $m^3$/ha) in all forests is almost double that (54 $m^3$/ha) in northern Finland.

Mainly as a result of intensive management practices the forest resources have increased in volume and value terms very rapidly during the past few decades. For example, the mean volume of the growing stock has increased by about 50 % and the annual growth by as much as 60 % in private forests during the past 50 years.

Table 1: Mean Volume of the Growing Stock on Productive Forest Land by Ownership in 1977-1984 ($m^3$/ha)

| Ownership | Southern Finland | Northern Finland | Total |
|---|---|---|---|
| Private | 106.8 | 55.0 | 91.5 |
| Companies 78.0 | 50.7 | 71.3 | |
| State | 82.5 | 52.3 | 57.0 |
| Others | 92.2 | 59.6 | 77.6 |
| All | 101.2 | 53.7 | 80.9 |

Source: Yearbook of Forest Statistics, 1988

The wide variations in climate and soil quality by region are reflected in the annual growth rates of forests, as shown in Table 2. Under favorable growing conditions in southern Finland well-stocked forests grow at a rate of 5.9 $m^3$/ha/year, while in the harsh climate of Lapland poorly-stocked forests can only reach a growth rate of 1.3 $m^3$/ha/year. Annual growth rates in other regions are between these two extremes; in eastern and western Finland the forests are capable of growing at a rate of 4.8 $m^3$ and 3.9 $m^3$ per hectare per year, respectively. In western Finland the productivity of the forests is greatly affected by terrain and soil quality; the forests are mostly situated on low lands and the share of drained peatlands is high. The large proportion of peatland is one of the main reasons why the forests in northern Ostrobothnia and Kainuu grow slowly, i.e. at an annual growth rate of 2.3 $m^3$ per hectare.

Table 2: Mean Annual Growth of the Growing Stock on Total Productive Forest Land in 1977-1988 ($m^3$/ha/a)

| Region | | Year of Inventory | Mean Annual Growth |
|---|---|---|---|
| I | Southern Finland | 1986-88 | 5.9 |
| II | Western Finland | 1977-84 | 3.9 |
| III | Eastern Finland | 1977-84,1986-88 | 4.8 |
| IV | Northern Ostrobothnia and Kainuu | 1977-84 | 2.3 |
| V | Lapland | 1977-84 | 1.3 |
| | TOTAL FINLAND | | 3.5 |

Source: Yearbook of Forest Statistics, 1988

The development class distribution of productive forest land by ownership is given in Table 3. A development class is usually rather closely related to an age class, but gives a more comprehensive picture of the general condition of a stand. The low-yielding stands may not have any relationship with age classes, however.

Table 3: Distribution of the Development Classes on Productive Forest Land by Ownership in 1977-1984

| Area and Ownership | Development Classes of Stands<br>1 | 2 | 3 | 4 | 5 | 6 | 7 | Low-<br>yielding | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | | - Share of Forest Land, % - | | | | | |
| SOUTHERN FINLAND | | | | | | | | | |
| Private | 2.4 | 8.0 | 15.4 | 19.8 | 27.3 | 16.0 | 1.8 | 9.3 | 100.0 |
| Companies | 2.2 | 10.9 | 26.3 | 26.2 | 16.7 | 13.0 | 0.8 | 3.9 | 100.0 |
| State | 2.3 | 8.2 | 23.5 | 25.9 | 13.9 | 17.2 | 1.1 | 7.8 | 100.0 |
| Others | 2.5 | 8.6 | 20.4 | 21.0 | 20.1 | 17.5 | 2.1 | 7.8 | 100.0 |
| All | 2.4 | 8.4 | 17.5 | 21.0 | 24.9 | 15.8 | 1.6 | 8.5 | 100.0 |
| NORTHERN FINLAND | | | | | | | | | |
| Private | 3.7 | 7.1 | 19.0 | 24.7 | 15.6 | 11.2 | 1.3 | 17.2 | 100.0 |
| Companies | 2.4 | 9.6 | 26.7 | 26.1 | 13.7 | 10.7 | 0.6 | 10.1 | 100.0 |
| State | 3.0 | 6.7 | 18.1 | 19.3 | 11.2 | 16.8 | 2.5 | 22.4 | 100.0 |
| Others | 3.8 | 5.8 | 15.9 | 18.3 | 13.5 | 19.7 | 1.8 | 21.2 | 100.0 |
| All | 3.3 | 7.0 | 18.8 | 22.0 | 13.4 | 14.2 | 1.8 | 19.4 | 100.0 |
| TOTAL FINLAND | | | | | | | | | |
| Private | 2.8 | 7.8 | 16.5 | 21.3 | 23.8 | 14.6 | 1.6 | 11.6 | 100.0 |
| Companies | 2.2 | 10.6 | 26.4 | 26.2 | 16.0 | 12.4 | 0.7 | 5.4 | 100.0 |
| State | 2.9 | 7.0 | 18.9 | 20.4 | 11.7 | 16.8 | 2.3 | 20.1 | 100.0 |
| Others | 3.1 | 7.4 | 25.8 | 19.8 | 17.1 | 18.5 | 2.0 | 13.8 | 100.0 |
| All | 2.8 | 7.8 | 18.0 | 21.4 | 20.0 | 15.1 | 1.7 | 13.2 | 100.0 |

Development Classes:

1. Open area or seed tree stand
2. Small seedling stand
3. Advanced seedling stand
4. Young thinning stand
5. Advanced thinning stand
6. Mature stand
7. Shelterwood stand

Source: Yearbook of Forest Statistics, 1988

## INTENSITY OF FOREST RESOURCE USAGE

Because wood-based products generate close to 40 % of the country's export earnings, one of the principal objectives of forestry policy in Finland has been to utilize fully the growing potential of the forests. As a result, the utilization of forest resources for industrial purposes in Finland has been among the most intensive in the world, if not the most intensive.

The ratio between the mean annual cutting volume in private forests in 1986-1988 and the Annual Allowable Cut (AAC), as given in Table 4 below, shows the intensity of forest resources usage. The annual cutting volume in relation to the AAC varied from 81 % in southern and western Finland to 107 % in Lapland, while in eastern Finland the ratio was 86 % and in northern Ostrobothnia and Kainuu 90 %, respectively. However, it has to be kept in mind that cutting volumes fluctuate from year to year because of the cyclical nature of international forest products markets.

Table 4: Ratio between Mean Annual Cutting Volume and AAC in Private Forests (1986-1988 averages)

| Region | | Cutting Volume* | Allowable Cut | Ratio |
|---|---|---|---|---|
| | | - mill. $m^3/a$ - | | |
| I | Southern Finland | 15.60 | 19.18 | 0.81 |
| II | Western Finland | 9.20 | 11.38 | 0.81 |
| III | Eastern Finland | 12.10 | 14.07 | 0.86 |
| IV | Northern Ostrobothnia and Kainuu | 3.85 | 4.27 | 0.90 |
| V | Lapland | 3.02 | 2.82 | 1.07 |
| | TOTAL FINLAND | 43.78 | 51.72 | 0.85 |

* incl. logging and silvicultural waste

Source: The Finnish Forest Research Institute and The Forest 2000-Programme

The ratios shown above indicate that at least in 1986-1988 the forest resources in the northern parts of the country were fairly fully utilized; in Lapland even some overcutting seems to have taken place temporarily. The forests in the other parts of the country were underutilized in 1986-1988.

Changes in the forest ownership structure and alternative uses of forests for recreational purposes at the expense of wood production are considered major reasons for under-utilization. In addition, the accelerated fragmentation of forest holdings (Table 5) seems to have a negative effect on the timber supply from private forests. However, it has to be kept in mind that there are active forest owners, who want to expand their forest land to intensify wood production. There also exists a mismatch between species required by the forest industry for different processes and species actually available for supply from forests. In particular, there is oversupply of large-dimension spruce while there is a shortage of birch pulpwood. The demand for and supply of timber is anticipated to become more balanced by the mid-1990s, provided that the present expansion plans of the pulp and paper industry will be carried out.

Table 5: Distribution of Private Forest Holdings by Size Class and Region (1985-1987 averages)

| | Size Classes, ha | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | <5 | 5-20 | 20-50 | 50-100 | 100-200 | >200 | Total | Total Number** | Forest Land 1000 ha |
| | | | - Share of Total Number* - | | | | | | |
| I | 35.1 | 36.1 | 20.4 | 6.2 | 1.7 | 0.5 | 100.0 | 159 061 | 3 117.9 |
| II | 40.4 | 25.4 | 24.8 | 7.4 | 1.6 | 0.4 | 100.0 | 108 674 | 2 321.2 |
| III | 24.3 | 30.4 | 30.0 | 11.5 | 3.1 | 0.7 | 100.0 | 89 997 | 2 600.4 |
| IV | 39.1 | 10.2 | 25.3 | 19.3 | 5.2 | 0.9 | 100.0 | 39 247 | 1 405.0 |
| V | 38.5 | 3.6 | 16.4 | 22.0 | 16.6 | 2.9 | 100.0 | 29 190 | 1 946.8 |
| TOTAL | 34.8 | 27.6 | 23.7 | 9.9 | 3.3 | 0.7 | 100.0 | 426 169 | 11 391.3 |

* excl. forest holdings yielding less than 20 $m^3$ per year

** if the person owns forest land in two or more municipalities, it is included in the statistics as seperate holdings

I Southern Finland
II Western Finland
III Eastern Finland
IV Northern Ostrobothnia and Kainuu
V Lapland

Source: Yearbook of Forest Statistics, 1988

## DATA BASE

For the reasons stated previously, the profitability evaluation of private forestry in Finland has been conducted using aggregate regional data. The data have been collected by means of a desk study. The major sources which have been used in the data collection are: (i) The official yearly statistics published in the Yearbook of Forest Statistics and other data published or made regularly available by the Finnish Forest Research Institute. (ii) Progress reports and other data kept by KML Tapio, the Central Board of Private Forestry in Finland. (iii) Data bank established under the project "Profitability of Private Forestry" at Pellervo Economic Research Institute.

The data were collected for the years 1986-1988 to compute the three-year means for the analysis. It should be noted that almost all the data for 1988 are preliminary by nature and thus subject to revision.

The results of the profitability analysis are given in Finnish Marks (FIM). All the results were converted to 1988 monetary levels by using the Consumer Price Index as a deflator.

## RESULTS

The gross and net income obtained by private forest owners from forestry in Finland are shown in Table 6. The results of the computations are given in the form of the minimum standard set up by the IUFRO Project Group.

Table 6: Aggregate Gross and Net Income of Private Forest Owners (1986-1988 averages in constant 1988 terms)

| Income and Costs | Southern Finland | Western Finland | Eastern Finland | Northern OB and Kainuu | Lapland | Total Finland |
|---|---|---|---|---|---|---|
| | | million FIM | | | | |
| Gross income | 2 357.7 | 1 263.1 | 1 750.8 | 447.6 | 353.1 | 6 172.3 |
| Less direct costs | 299.1 | 247.8 | 298.1 | 110.1 | 131.2 | 1 086.1 |
| RESULT I: INCOME OF THE FAMILY | 2 058.6 | 1 015.3 | 1 452.7 | 337.5 | 221.9 | 5 086.2 |
| Less value of own work | 299.2 | 176.2 | 221.4 | 71.9 | 83.4 | 852.1 |
| RESULT II: NET INCOME BEFORE INCOME TAX | 1 759.4 | 839.1 | 1 231.3 | 265.6 | 138.5 | 4 234.1 |
| Plus state subsidies | 30.5 | 44.7 | 44.2 | 30.7 | 72.5 | 222.5 |

The total gross income of forest owners amounted to FIM 6 172 million in constant 1988 terms, including work income from delivery sales. After deducting all direct costs the income of families reached FIM 5 086 million (i.e. Result I). After deducting the value of the own work inputs used for delivery sales and for stand establishment and maintenance, the net income before income tax totalled FIM 4 234 million (i.e. Results II). All the costs added up to FIM 1 938 million, i.e. their share of the gross income was 31 %. This means that 69 % or FIM 4 234 million was left to cover income tax and to provide a return on capital invested.

To arrive at the net income before income tax, inclusive of direct subsidies, the State subsidies of FIM 223 million have to be added to Result II.

The results of the profitability analysis differ greatly by region. The share of total costs of the gross income varies from about 25 % in southern Finland to 61 % in Lapland. In other words, in southern Finland the share of the net income (i.e. Result II) was as high as 75 %, while in Lapland it was very low, only 39 %. The results imply that the profitability of forests in different regions in Finland is largely determined by the growing potential of the forests. The low productivity of the forests in the northern parts of the country seems to justify the subsidies and grants directed annually by the Government to these areas.

Even if subsidies are included, the net income per cubic metre cut in northern Finland is two thirds that in southern Finland. If the subsidized incomes per hectare are compared, the regional variation becomes even wider, i.e. FIM 533/ha in southern Finland vs. FIM 96/ha in northern Finland (Table 7).

Table 7: Net Income per Cubic Metre and per Hectare from Private Forests (1986-88 averages, in constant 1988 terms)

| Region | | Net Income* | Subsidies | Net Income* | Subsidies |
|---|---|---|---|---|---|
| | | FIM/m³ | | FIM/ha | |
| I | Southern Finland | 113 | 2 | 524 | 9 |
| II | Western Finland | 91 | 5 | 285 | 15 |
| III | Eastern Finland | 102 | 4 | 432 | 16 |
| IV | Northern Ostrobothnia and Kainuu | 69 | 8 | 138 | 16 |
| V | Lapland | 46 | 24 | 63 | 33 |
| | TOTAL FINLAND | 97 | 5 | 319 | 17 |

* before subsidies and income tax

The structure of gross and net income per cubic metre confirms that not even the high subsidies in Lapland compensate for the lower net income received by the forest owners per cubic metre (Table 8). On the one hand, in Lapland stumpages are lower than in other parts of the country because of high logging costs. On the other, direct costs per cubic metre in Lapland are more than twice the costs in southern Finland.

Table 8: Gross and Net Income per Cubic Metre from Private Forests
(1986-88 averages, in constant 1988 terms)

| Income and Costs | Southern Finland | Western Finland | Eastern Finland | Northern OB and Kainuu | Lapland | Total Finland |
|---|---|---|---|---|---|---|
| | | | FIM/$m^3$ | | | |
| GROSS INCOME AND DIRECT COSTS | | | | | | |
| Plus stumpages | 135.5 | 123.0 | 132.0 | 102.8 | 98.6 | 126.4 |
| Plus work income from delivery sales | 15.7 | 14.3 | 12.7 | 13.5 | 18.3 | 14.6 |
| Less stand establishment and maintenance costs | 7.5 | 11.4 | 12.2 | 12.1 | 21.8 | 11.0 |
| Less forest improvement costs | | | | | | |
| · drainage | 1.2 | 2.2 | 1.2 | 3.7 | 3.3 | 1.8 |
| · road building | 3.0 | 5.1 | 3.4 | 5.8 | 9.7 | 4.2 |
| Less forest administration | | | | | | |
| · forest management plans | 0.2 | 0.3 | 0.2 | 0.4 | 0.9 | 0.3 |
| · other costs | 3.8 | 4.5 | 4.6 | 4.6 | 6.1 | 4.4 |
| Less silvicultural fee | 3.5 | 3.4 | 3.1 | 2.1 | 1.8 | 3.1 |
| RESULT I: INCOME OF THE FAMILY | 132.0 | 110.4 | 120.1 | 87.7 | 73.5 | 116.2 |
| VALUE OF OWN WORK | | | | | | |
| Less in delivery sales | 15.7 | 14.3 | 12.7 | 13.5 | 18.3 | 14.6 |
| Less in stand establishment and maintenance | 3.5 | 4.9 | 5.6 | 5.2 | 9.3 | 4.9 |
| RESULTS II: NET INCOME BEFORE INCOME TAX | 112.8 | 91.2 | 101.8 | 69.0 | 45.9 | 96.7 |
| Plus state subsidies | 2.0 | 4.9 | 3.7 | 8.0 | 24.0 | 5.1 |

Because private forest holdings in Finland are very small, i.e. 20 to 29 hectares in high-yielding areas, compared with 36 to 67 hectares in low-yielding areas, the owners' net earnings from forests vary on an average from FIM 4 700 to FIM 13 700 (Table 9). In reality, the earnings of an individual forest owner might be higher, taking into account that in some cases the forest holding under the same ownership comprises separate woodlots in different municipalities (See footnote of Table 5).

Table 9: Mean Size and Average Net Earnings of Private Forest Holdings

| Region | | Mean Size of Productive Forest Land on Forestry Holdings, ha | Average Net Earnings FIM/Forest Holding* |
|---|---|---|---|
| I | Southern Finland | 20 | 11 100 |
| II | Western Finland | 21 | 7 700 |
| III | Eastern Finland | 29 | 13 700 |
| IV | Northern Ostrobothnia and Kainuu | 36 | 6 800 |
| V | Lapland | 67 | 4 700 |
| | TOTAL FINLAND | 27 | 9 900 |

* in constant 1988 terms, before income tax

Overall, the share of forest income of forest owners' total net earnings is fairly low. On the basis of the latest income and taxation statistics, share of forest income, including work income, of the total net earnings of an average farm forest owner has been 15 to 20 %, before income tax. In the households of non-farm forest owners the role of forest income is even less significant. Individual and annual variations are, however, rather large.

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# Voluntary Paper Summaries
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# UNE MEILLEURE SYNERGIE DES RESSOURCES HUMAINES POUR LA PLANIFICATION ET L'AMENAGEMENT

par J.H. BARTET

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FDC: 62--015.5

Dans les années 70, la recherche en modélisation forestière, que ce soit en France ou en Suisse a été une affaire de spécialistes. A la tradition de voir les débats sur la planification forestière et l'aménagement réservés aux ingénieurs et aux chercheurs s'ajoutait le mystère du nouvel outil informatique limité à quelques pionniers considérés presque comme sacrilèges.

Depuis quelques années, l'évolution de l'Office National des Forêts provoque un profond changement : Chaque échelon des actions forestières se trouve de plus en plus impliqué dans le processus de planification et de modélisation ce qui influe à la fois sur la structure des modèles et des aménagements ainsi que sur leur mode d'élaboration.

## Le processus de planification des forêts publiques

Pour les forêts appartenant à l'Etat et aux communes, des orientations locales d'aménagement viennent d'être élaborées par région forestière, grâce à un travail de spécialiste.
Ceci permet aux techniciens de terrain d'élaborer eux-mêmes plus facilement les aménagements planifiant chaque unité forestière. Ils apportent, ainsi, le pragmatisme du terrain et inversement concrétisent plus rapidement sur le terrain les orientations régionales.

## La mise en place de logiciels d'aide à l'aménagement

La diffusion des outils informatiques accélère ce processus en donnant aux techniciens de terrain l'accès à des logiciels qui permettent une rapidité et une puissance de calcul inédite. Le dialogue entre le praticien et le planificateur peut s'effectuer en temps réel, avec une évaluation instantanée des hypothèses.

## La liaison terrain-recherche pour utiliser les modèles de croissance pour les éclaircies

Dans le massif de pin maritime des Landes de Gascogne, les possibilités de liaisons informatiques permettent, maintenant, aux techniciens de terrain d'avoir un accès direct aux modèles de croissance, même en cours de mise au point. Le praticien peut, ainsi, évaluer immédiatement l'effet d'une coupe. Inversement, il fournit des données qui affinent le modèle.

Ce processus oblige la planification et les modèles qu'elle utilise, à être plus pragmatiques et accessibles aux forestiers de terrain. Inversement, il enrichit les modèles, de la pratique quotidienne du terrain et démultiplie considérablement leur champ d'utilisation. Enfin, il permet que le responsable de chaque niveau ait conscience de sa contribution et s'approprie, ainsi, la démarche de planification.

# ANALISIS DE LA EFICIENCIA DE ESTRATEGIAS DE MANEJO SILVICOLA RENOVABLES

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## RESUMEN

FDC: 62: (72)

En este estudio se discuten las implicaciones de las estrategias de manejo silvicola tradicionales (EMS) sobre la eficiencia biologica y economica del uso de los recursos para la produccion maderable. Se propone un procedimiento para optimizar la seleccion de prescripciones de manejo silvicola. Utilizando un caso real para un ejido forestal en el estado de Durango se demuestra la aplicabilidad de las tecnicas de optimizacion usadas para evaluar EMS. Conclusiones que no es posible maximizar los beneficios de esta empresa forestal si se continuan aplicando estrategias clasicas de cultivo como los del Metodo de Desarrollo Silvicola.

## SUMMARY

In this study, the implications of the use of traditional silvicultural management prescriptions (EMS) are discussed in terms of biological and economic efficiency in the use of resources for forest biomass production. A procedure is proposed here for the optimal selection of silvicultural management prescriptions. Utilizing a case study of a forest ejido in the state of Durango, the applicability of optimization techniques is demonstrated in evaluating EMS's. We conclude that it is not possible to maximize the benefits of this forest firm if classical cultivation strategies such as the Method of Silvicultural Development continue to be applied.

# SEEDLING PRODUCTION SYSTEMS FOR THE 1990S - AN ANALYSIS

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**Thanks to modern nurseries producing container seedlings, the forestry sector today can carry out artificial regeneration with container seedlings at a lower cost than if it used bare-root seedlings. In spite of the major advantages afforded by the use of container seedlings, there are drawbacks, particularly with regard to working conditions in the nursery for some elements of work.**

**Today´s nurseries were established during the 1970s and 1980s, and substantial investment is likely to be required in the coming decade. For this reason, analysis is now imperative to determine the costs of tentative types of seedling-production system. The present study has examined the production costs in four systems for producing one-year container seedlings.**

**The analysis demonstrates that the lowest costs, of about SEK 600 per 1000 seedlings, are achieved using the system in which seedlings are grown without the need for any outdoor growing period. Indeed, the cost advantage that this system has over the other systems included in the analysis provides scope for increasing the capital investment by 10% or more. However, a high level of risk is associated with the system, as shown in the analysis. The main problem is the uncertainty attached to whether it is biologically viable to produce seedlings suitable for outplanting, by growing them for a period of about four months in an artificial environment. The analysis therefore highlights an important area in which further research is necessary, that is, to establish, through practical trials and studies, whether the growing methods are biologically viable using the technology that is available but as yet unproven.**

**Today´s conventional systems are still more competitive in terms of costs (under SEK 700 per 1000 seedlings) than the other systems studied.**

# PROBLEMAS ECONOMICOS DEL APROVECHAMIENTO ENERGETICO DE RESIDUOS DE BIOMASA FORESTAL. APORTACION DEL SECADO NATURAL

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FDC: 847.1: 839.819

## RESUMEN

El secado natural puede ser, en países de climas benignos, un método eficaz para rentabilizar el aprovechamiento de los residuos de biomasa forestal con fines energéticos, al disminuir, por termogénesis, el porcentaje inicial del contenido en agua de los materiales, hasta convertirlo en combustible apto para su utilización directa.

Palabras clave: Biomasa forestal, secado natural, aprovechamiento energético, termogénesis.

## SUMMARY

Natural drying may be, in countries with benign climates, an efficient method for making worthwhile use of forest biomass waste to produce energy. It decreases, by thermogenesis, the initial water content percentage in the waste materials, thus converting them into fuel suitable for direct use.

Key words: Forest biomass, natural drying, energy production, thermogenesis.

convencionales.

# WORK STUDY IN FORESTRY

# THE NEED TO WORK IN STANDARD TIME

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## SUMMARY

FDC: 305

There is a need for standardisation of time measurement. Standard Time is the most appropriate. It states the true work content of a job and is the established practice in industry generally, and in forestry in Britain. British procedures for production of Standard timetables are discussed. Results are audited by check study procedures and validate the use of Standard time as the measure of work content in forestry.

Key words, Standard Time, Performance Rating, Elemental Breakdown, Check Studies.

# COMPARISONS OF ANIMATED SIMFACTORY AND GPSS/PC COMPUTER SIMULATIONS OF FOREST OPERATIONS

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Discrete computer simulation is one in which only discontinuous events occur. Animated simulation can be defined as viewing of a simulation utilizing user-chosen shapes moving under user control. The two- or three-dimensional shapes mimic real-life objects and are typically in color. SIMSCRIPT II.5's SIMFACTORY (CACI) is a menu-driven PC-software that allows a simulation model to be easily animated. Results can be continuously viewed and also printed when specified. With SIMFACTORY the need to formally program in code is non-existent. Icons that represent viewed objects in the animated system have been specifically drawn to represent real-life objects in the modeled system. The objects can be color-coded corresponding to their natural color or to represent by color changes a current physical status of the objects. Objects can be stationary or can move to portray spatially the activities that occur within the system. If a woodyard were the focus of an animation, movable objects would include trucks, tree-length logs, slashed bolts, and debarked bolts. Stationary objects would include a scaling station, unloading equipment, slasher, debarker, and conveyor (or chipper). As the simulation executes the movable objects change their positions in a life-like way. The physical status as to the availability of the stationary objects would be color coded, e.g. awaiting wood resource flow, actively processing or servicing, down, etc. Color changes imply changes in status. The queue areas would have dynamic "windows" of numerical values representing, for example, their current queue contents.

Like SIMFACTORY, simulation under GPSS by its very nature is what can be termed case-oriented - that is a successful implementation of a GPSS model depends upon not only knowing GPSS as a language system but fully understanding the case (environment) being modeled. Hence it can be considered a user's language as opposed to the language of a professional programmer. It is intended that the engineer, manager or scientist most familiar with the environment to be modeled assume the direct role as a programmer. However, GPSS and other simulation approaches have been designed to recognize and accommodate the fact that many different problems have similar traits. For example, they may involve queues, provide common forms of statistical information, or have dynamic and static properties whose status can be evaluated discretely through time. A system conceived under GPSS is made up of static and dynamic components. The model through a computer program represents a sequence of discrete events in which these components participate. A program is made up of a sequence of GPSS commands called "Blocks" each inferring an "operation" which is modified by a unique set of "operands". A program also contains definition and control statements as appropriate. Simulation then becomes the computer manipulated flow of the dynamic components through the model. While not true animation, GPSS/PC (Minuteman Software) allows dynamics viewing. WINDOWS displayed in color on a computer monitor offer a visual portrayal of the system in action. As transactions move through the modeled system, the displays are updated continuously. In fact, the transactions can be "stepped through" the system one discrete event at a time. WINDOWS that are typically useful include: a display of blocks that constitute the static elements of the model as defined by the user; bar diagrams with corresponding numerical values that enlarge or reduce as status changes occur for facilities, storages, and queues; matrices whose cell values fill or change as user-desired results are updated; and MICROWINDOWS to display selected results whose values are of particular interest throughout the simulation. Animation possibilities under GPSS will be the subject of future discourse.

# IMPORTANCE OF DRAFT ANIMALS IN TIMBER HARVESTING PRACTICES IN DEVELOPING COUNTRIES

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## SUMMARY

FDC: 307: (213)

For centuries, draft animals have been used in agriculture and forest operations. Their importance is more evident in developing countries, where animals are the principal source of traction. Animals provide important benefits in terms of their low cost, because they cause very little environmental damage, because they use mainly local inputs, and because they are better adapted to small scale operations.

In this paper, characteristics and limitations of the use of oxen in logging operations in Costa Rica, are discussed. Some research results that have contributed to reduce these limitations and make the operations more efficient, are also presented.

Finally, results of time/production studies is included. This information is compared with the costs from larger logging operations in which mechanized harvesting systems are used.

Keywords: harvesting, draft animals, developing countries

# THE MEASUREMENT OF DRAWBAR PULL FORCES OF SILVICULTURAL IMPLEMENTS

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## SUMMARY

Determining the drawbar pull requirements of silvicultural implements and the usable drawbar pull generated by the prime movers in various site and soil conditions is an essential step in the proper matching of prime mover and implement. It is also useful in the design or modification of machines for silvicultural operations. Therefore, FERIC began a series of tests in 1988 to measure the drawbar pull requirements of rear-mounted implements that use a hitch or mainline system.

The paper reviews the methods and the instrumentation FERIC uses for the measurement of the drawbar pull forces of silvicultural implements. Some interim results for different site preparation implements, such as patch scarifiers, forestry disc harrows and drags, are presented. The influences of site conditions on the drawbar pull forces are also discussed.

# PREVENTION OF POSTURAL DAMAGE IN LOGGING OPERATIONS

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FDC :304

A study on the prevention of osteoarticular damage due to mechanical overload in workers of the Forest Service of the Autonomous Province of Trento is carried out.

It deals with a working population of about 500 subjects concerned mainly with logging operations and who work in difficult alpine conditions particularly because of the steep slopes.

The study is divided into three phases: 1. the evaluation of risk; 2. the evaluation of the osteoarticular damage to the spine and to the large articulations; 3. back school activity.

The mechanical overload is evaluated by specific assessments in working conditions by using simplified bio-mechanical methods which provide quantitative estimates of the loads at the level of rachis and of the other articulations which are most affected (mainly the upper limbs). The results of these measurements are critically analysed on the basis of standards and criteria found in the literature.

The clinical-functional evaluation of the chronic-degenerative alterations of the rachis is performed using experimented protocols which include a questionnaire for the anamnestic study of the acute and chronic disturbances of the spine according to pre-determined threshold values, as well as a visit which involves: the analysis of bodily attitude, in particular the presence of asymmetries, scoliosis, alterations of the kyphosis and lordosis curves; pressing and palpations of the spinal apophyses, of the inter-vertebral spaces and muscles, in order to discover possible pains; a study of the motility of the rachis; study of the general motility.

The clinical-functional evaluation of some of the large articulations such as the shoulder, the elbow, the wrist and the knee is carried out using protocols which include: an initial anamnestic study which is considered to give positive result when a given threshold value is reached; pressing and palpations; study of the analytic motility.

The results, concerning the prevalence of both anamnestic and clinical data, are analysed by comparing them with those relative to suitable control groups (not exposed to postural risk) subdivided into age classes.

Finally, the main actions are identified for the prevention of vertebral pain and for the functional recovery of the workers affected by rachis pathology.

The preventive back school is necessary for all personnel with the main aim of informing all the workers about how to correctly perform the daily working movements in order to avoid damages to the column.

The educational and rehabilitational back school is only for workers affected by pathologies and its aims are to teach the correct daily and working movements, and to recover the functional ability of the workers by means of a series of pain-relieving exercises, to be learned at the back school and to be continued daily at home.

# COMPARISON OF DIFFERENT DELIMBING DEVICES FOR CRADLE TYPE MULTI-STEM DELIMBERS

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Forest industry is in many places over the world facing a situation with an increasing proportion of small-sized trees in forest harvestings and of smaller piece-sizes due to an increased utilization of the stems. Multi-stem technique is one way to to rationalize the operations of harvesting. Multi-stem delimbing is of particular interest, as it is commonly the most labour intensive and costly operation of forest harvesting operations.

Multi-stem delimbers of the cradle type can be constructed very flexible to suit different conditions and the flat inner surfaces of the cradle facilitates the use of actively driven delimbing devices. A study was conducted to compare different types of delimbing devices for cradle type delimbers. The study was performed separately for two tree species, Scots pine (*Pinus silvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.). An experimental rig was built and the delimbing devices were mounted in one of the long sides, between the conveyor chains. The conveyor accomplished the tumbling of the trees in the cradle. Four different types of delimbing devices were tested: fixed knives, open rollers, closed rollers and rotors.

The fixed knives, wich were the only devices not actively driven, were found to be less effective than the other devices. The rotors proved to be the most efficient type of the delimbing devices. To delimb Norway spruce efficiently, the delimbing devices have to be provided with sharp edges, which is not as important for Scots pine. The diameter of the rotor influence the efficiency of the delimbing device.

The results point out that by the delimbing devices used greatly affects the delimbing and by choosing a more efficient delimbing device improvements can be made in the performance of cradle type delimbers.

# CABLE YARDING IN SOUTHERN AFRICA: AN ANALYSIS OF ITS PRODUCTIVITY AND POSSIBLE PROCEDURES FOR ITS IMPROVEMENT

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FDC: 375.1: (68)

With the expanding demand for timber in southern Africa, steeper slopes are being afforested. This, coupled with evidence of serious soil compaction and erosion damage being incurred by infield harvesting machinery, could lead to a substantial increase in the use of cable yarding.

Currently, most cable yarding machines in southern African countries are of up to one-ton capacity per haul and typically produce up to 60 tons of timber per day. These production rates are compared with those of larger machines used in New Zealand and North America where rates of 200 to 400 tons per day are reportedly achieved. Owing to the high cost of these large machines, investigations were initiated to maximise the productivity of the small ones.

Studies conducted on local machines demonstrated sizable losses in productivity. Choking and dechoking times were found on average to be more than three times longer than what could easily be achieved while carriage speeds were 23 % of what might be regarded as an efficient speed. Average load masses were 61 % of those rated for the machines, but were frequently as low as 50 %. Without major breakdowns, delay times ranged from 21 to 49 %. Trials showed that difficulties in choking and dechoking were overcome by using tag lines which permitted prechoking. This benefit increased with decreasing stem size. Carriage speed was inhibited by machine design being such that either only one speed was available or if several gear ratios were available they were awkward to engage. Load masses were low owing to there being no prechoking and the use of plain, non-locking carriages. These carriages require considerable braking on their haul-back lines to effect any lifting of loads. Thus, much of the machine's power and capacity was used in this manner instead of in conveying the load.

Through the implementation of these improvements, the productivity of small cable yarders costing about one fifth to a tenth of the larger machines could be brought to within at least a half of the daily production of the larger machines.

**Keywords:** Cable systems, highlead, skyline, soil compaction, soil erosion.

# OCCUPATIONAL ACCIDENTS AND WORKING CONDITIONS IN NIGERIAN LOGGING AND WOODWORKING INDUSTRIES: A CASE STUDY

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FDC: 304: (669)

In recent years scientists in a number of developing countries have successfully conducted basic studies on accidents and working conditions in the Forestry and Woodworking industrial sectors of their countries. Such studies aimed at defining the situation of occupational safety and health of workers led to remedial programmes for improvement. However, in Nigeria, this subject has never received any serious attention.

Studies aimed at collecting data on job accident occurring in logging, sawmilling and plymilling operations for the period 1980/81 to 1987/88 were conducted using available medical/company records and by the recall method. Information on working conditions relating to safety regulations, general condition of equipment, provision of first aid and accident compensation was gathered by interviews and the use of ergonomic checklist.

The two companies which formed the object of this study are in this summary indicated as A and B. The study revealed that both companies showed a tremendous reduction in the number of workers during the period, the number dropped in A in 1980/81 from 3453 to 1154 in 1983/84 with a slight rise to 1400 in 1987/88. The number of workers in B dropped from 680 to 300 during the period. Analysis of accidents in A showed that a total of 1005 injuring accidents occurred during the period and from this 280 or 27.88% were disabling injuring accidents plus two fatalities. There was an overall lowering of the number of accidents during the period, the highest figure being in 1982/83 and the lowest in 1986/87. The Gross Frequency Rate (No of all types of injuring accidents per million man-hours worked) was 64.64, 44.06, 62.82, 11.15 and 23.93 for 1983/84, 1984/85, 1985/86, 1986/87 and 1987/88 respectively while the Severity Rate (No of days loss per million man-hours worked) for the same years above in the same order was 168.23, 166.81, 269.58, 1866.00, 63.48 respectively. Except in 1987/88 when sawmill recorded the highest percentage man-days loss of 27.67%, logging had the highest for the period. Body parts injured in 1987/88 were mainly finger and leg. Most disabling injuries in logging occurred during felling and delimbing. Unsafe Acts accounted for 61.2% of total accidents leaving Unsafe Conditions with 38.8%. Agents of accidents were mainly materials handled and vehicles/trucks. Company B recorded officially only 14 accidents between 1984/85 and 1987/88.

In both companies safety regulations existed. Goggles, hand gloves and safety shoes were supplied but their use was not strictly enforced in B. On-the-job training was slack in B. There were no unguarded machines in both companies. Company B had no Medical Centre but an Ambulance with a nurse visited workers in the Forest Camps weekly. First Aid was available in both companies. The non-existence of trained safety personnel was evident in B. Accident compensation for injured workers was by insurance. Although the results of this study look fair for A, efforts should be intensified to reduce these accidents through training and protective wears.

# CO-OPERATIVE FARMER FORESTRY
# AND
# RURAL DEVELOPMENT

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## SUMMARY

FDC: 944: (417)

The west of Ireland is a region of dense rural population, many of whose livelihood is from farming the poor wet soils of the region. It has recently been discovered that the poor wet mineral soils which predominates, affording subsistance livestock farming, is highly productive for growing trees especially sitka spruce. Only 5% of the land is afforested at present.

The historical antipathy towards forestry meant farmers refused to avail of generous EC afforestation grant aid*. The approach of forest developers (who did avail of this grant), in buying up and afforesting farms, at prices that could not be matched by local farmers, developed open hostility towards all forms of forestry. Afforestation was seen as a land clearance movement by 'absentee' developers.

The co-operative movement saw the opportunities in forestry, as being one of the few natural resources available to provide a core, around which other self help community development could evolve. It set about changing the perception of forestry from that of rural depopulation agency into one of an instrument of integrated rural community development.

The new role for afforestation was welcomed by the EC Commission, who provided the co-operative, which was established to carry out this programme, (The Western Forestry Co-operative), with financial backing. This Society was formed in 1985. It worked closely with the National Farm Research Institute. As might be expected, the changing of deeply entrenched negative attitudes was initially a slow process. Now the Society is making significant progress. In 1986 it was involved with 6 farmers planting 30 Ha. By 1989 this figure had risen to 474 farmers with over 2,000 ha. A number of rural communities are actively developing integrated rural community programmes with forestry as its central focus. There is a healthy relationship between the co-operative and forest developers and state fores, so there is now a more planned approach to forest development with sensitivities for community needs and environmental/amenities requirements.

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*EC Reg 1820/80 provide an afforestation grant to farmers of 85% of cost.

# WOOD CUTTERS WITHOUT BACK PROBLEMS

## A multivariate factor analysis of a model for influence of work

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## SUMMARY

FDC: 302--015.5

The study "Wood-Cutters without Back Problems" is a multivariate factor analysis pointing out several factors which keep wood-cutters healthy and productive.

The most important of these factors is that a cutter with a healthy back does not strive to work as hard as the cutter with back pain does. Physical fitness and good work techniques do not help if the cutter cannot reduce the pace of his work when tired our under stress.

The study develops a model for many pressure influences on work load and production for wood-cutters.

A number of recommendations to cutters, forest worker schools and companies was the result of the study. It is important for the student at the forest worker school to develop self confidence and to feel secure and confident in his work. He must also be trained to trust his body's warning signals, for example, to distinguish between training stiffness and other kinds of pain.

## REFERENCES

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# ANALYSIS OF WHOLE-BODY VIBRATION LEVELS DURING SITE PREPARATION

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## SUMMARY

FDC: 302: 237.7--015.22

Motion-induced vibrations were measured on a sample of prime movers to determine the operators' daily whole-body vibration (w-bv) exposure levels. The influence of the machine characteristics, travel speeds, and terrain conditions on w-bv levels was quantified using the Principal Component Analysis (PCA) technique, and a non-linear hyperbolic model.

Acceleration levels were consistently higher than the acceptable limits (ISO 2631-1978 standard). The allowed daily exposure time, as evaluated under the Fatigue-Decreased Proficiency limits, was less than or equal to 2.5 hours in 100% of the cases. The PCA showed that front-mounted implements produced higher acceleration levels than rear-mounted units in all cases, and that tracked prime movers produced higher levels than wheeled ones. A strong correlation was found between the machines' mass/speed ratios and the acceleration levels in the x- and z-axis directions. In those axes, as the mass/speed ratios increased, the accelerations decreased. No correlation was found in the y-axis direction. This report shows that while w-bv levels in site preparation work are worse than in harvesting operations, it should be possible to reduce these levels by appropriate selection and matching of the prime mover and implement, as well as by operating at an optimal travel speed.

KEYWORDS: Whole-body vibration, Vibration analysis, Site preparation, Scarifying equipment, Prime movers.

# PSYCHO-SOCIAL STRESS OF FOREST MACHINE CONTRACTORS
## A macro-ergonomical approach to study the forest operations

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FDC: 302: 644.6

The role of contractors in forestry varies very widely from continent to continent and from country to country. The scale extends from quite independently operating contractors of large forest areas to small forest machine owners working as operators of their machines. The last mentioned ones are typical for the Nordic countries, where several psycho-social and economical studies on contractors have been carried out during the last few years.

In spite of long working days, economical troubles and ergonomical load, these hard working people seem to be rather satisfied with their job, and their health status is in many respects better than that of referents. On the other hand, some alarming features are also prevailing, one of those being ailments in shoulders and upper limbs. One explanation is that the personal profile of contractors is in good balance with the professional one. In other words, people suitable for this occupation have found a way to it. They however have a minimum education and inadequate knowledge of economical things. Many of them feel uncertain about the future. At the same time fast technical and information system development is going on.

In future, so called macro-ergonomical approach to study the changes in forest work and especially in the role of contractors may be useful. It means the examination of the whole production system at the same time including both technical and social features. There exist tendencies to change from the technology-centred approach to the human-centred one in applying the forest technology. Then, contractors and operators will have even greater role in introduction, steering and supervision of more and more advanced technology and technical systems. This kind of tendency challenges contractors to gain more theoretical knowledge as well as researches to step in the demanding methodology of the macro-ergonomics.

# MECHANICAL SITE PREPARATION IN MOUNTAINOUS TERRAIN IN BRITISH COLUMBIA

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## SUMMARY

FDC: 237.7: (23): (711)

Prescribed burning has been the traditional method of site preparation used in mountainous terrain in British Columbia. As burning becomes less desirable, alternatives must be found. Currently, flexible-tracked skidders, excavators, and motor-manual tools are used. However, with the exception of motor-manual tools, there are no alternatives yet available for undertaking site-preparation activities on most slopes over 40%.

Keywords: Mechanical site preparation, Mountainous terrain, British Columbia.

# PROFITABILITY OF PRIVATE FORESTRY IN THE NORDIC COUNTRIES

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FDC: 923.4: 671: (48)

During the last years studies of profitability in private forestry have been carried out within the Nordic Forest Owners Federation, NSF, covering Denmark, Finland, Norway and Sweden. A model has been set up to specify how the studied forest shall be described in forestry terms and how the economy shall be measured and presented. The model and studies are formed after the following guide-lines:

- The model is set up for studies of forestry with a rather continuous character (sustained yield forestry). From that follows that the present silvicultural operations shall aim to result in mature forests of about the same character (and value) as the forests that are actually being cut down (this is normally the case in private forestry in the Nordic countries).

- The economy of forestry is described in the same way as private and company economy in general. Profitability is defined and calculated as rate of yearly return on total working capital. Total working capital is normally equal to actual market value of forest farms in the studied area. The model thus is formed to describe local situations. National statistics are only used when the selection of representative examples is being made.

- The initially mentioned "continiuous character" of forestry hardly exist in reality. In the Nordic countries for example the standing volume in private forests has steadily increased during a long period. The increase of standing volume results in an increase of market value of the forest farms which is difficult to measure. In the model we have chosen the following way to handle this problem:
  First the model describes the measured activity of the actual year (volume and net income from the actual cutting operations respectively volume and costs of actual silviculture operations). In a second step the operations are recalculated to a level that corresponds to a continiuous forestry (cuttings adjusted to yearly growth and other operations adjusted to keep an unchanged state of forest).

The studies give a map of profitability examples over 30 million hectars of private forests in the four Nordic countries. The average profitability as described above was in 1988 3,9 % return on total working capital. The variation between different examples was in 1988 from 0,15 % to 5,7 %. The calculation includes taxes, fees and subsideries directly connected with private forestry. Income tax and property tax is not included.

## ERGONOMIC AND MEDICAL PROBLEMS IN FORESTRY

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FDC: 302:304: 362.7

We have examined 1209 timbermen working with motor saw using the so called Nordic method of forest mining, i.e. above all sawing down, lopping and wood assortment by means of the saws Husquarna 162 SG and Partner R 121 T.

Measuring of the fall of the motor saw performance and prolongation of the cutting time after about 500 motor hours of the work. Following of the influence of bad maintenance and of bad saw adjusting. Following of vibration acceleration on the motor saw handles. Repeated clinical examinations of the group of timbermen and comparison of a group of young workers with a group of workers older than 50 years.

The vibration disease arises earlier in the timbermen than in the casting cleaners. The vibration disease syndrome of the vessels appears earliest and as late as after a longer time (about 2 years) we can observe joint and nerve vibration disease.
Important findings are given concerning a drop in performance of power saws after ca 30%; it was also found that by improver maintenance and wrong adjustment of the power saw the values of vibrations increased by 10%. In the set under study only 20% of forest workers older than 50 years were healthy - 80% of workers suffered from vibration disease.

Therefore principles of the dispensatory care of these forest workers were proposed, along with ergonomic principles of logging, according to which the duration of risk work should be reduced to ca. two hours a day, divided into six intervals having ca 20 minutes; there should be at least twofold intervals of no risk work included in these six intervals. Further ergonomic principles of the regime of work and rest are proposed.
In conclusion it is emphasized that the apprentices of the Forest Training Institutions should be subjected to ergo-medical and psychological examinations and they should be chosen for suitable specializations from the given forestry vocations.

# CONSEQUENCES OF DIFFERENT FOREST MANAGEMENT STRATEGIES -
# - AN EXAMPLE

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FDC: 923.4: 931: 62: (485)

## SUMMARY

The decision situation as well as the goal structure differ between different nonindustrial forest owners. As a result different owners apply different forest management strategies. A frame, at least in Sweden, when choosing strategy, is put up by the silvicultural law.

In this article we compare this frame expressed as Balance (recommended), Minimum and Maximum strategies with an Economic strategy. For the Economic strategy three different interest rates are used (0, 2 and 4%).

The strategies are applied during 100 years on a 75 hectares forest with quite normal age distribution in 1990. The result shows that in economic terms the Economic strategy is in almost all cases superior the others. However, the economic difference is not too big. One major difference can be noted. The Economic strategy results in a totally different forest than the Balance strategy. Volume is produced instead of quality.

During a one hundred year time perspective four to six different owners will be involved. Therefore we argue that it is important to apply an estate perspective. This means that the long term biological and financial stability of the forest is emphasized. This requirement is fulfilled by the Balance strategy. In addition this strategy gives volume as well as quality. Thus the strategy means also an insurance for an uncertain future. One shall never put all eggs in the same basket.

Key words: Nonindustrial private forest owners, decision situatin, goal structure, economic, net present value, decision support system.

# HARVESTING AND COMPLEXE UTILIZATION OF TREE FOLIAGE

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FDC: 331: 892.1

The utilization of branches of coniferous tree species has been studied, verified and realized.

When whole-tree technology is used, large amount of branches is accumulated at landings. These branches were recently burned without any effect directly at landings. With regard to known problems of the processing of these branches in woodworking and pulp and paper industry, we looked for nontraditional method of the utilization.

Branches collected beside limbing machines and processors are chipped by mobile chipper. Chips are sorted into two fractions: wood and tree foliage. Sorted tree foliage is transported by system of conveyers into drum drier where it is dried, reaching the moisture contents 10-12 %. Dried tree foliage falls into grinder where it is milled into feeding flour. Flour can be transported by pneumatic system on packing line and dispatched in sacks to consumers, or it is transported to bins which are part of granulating line. On granulating line hay, straw, groats, molasses, vitamin -rich components, biofactors and other feeding components are added into flour and granulated feedstuffs are produced according to receipts for particular kinds of animals. According to opinions of specialists from the field of livestock physiology with high doses of flour rumen digestion of animals can be affected by ethereal oils from tree foliage. Therefore tree foliage may be distilled before drying and in such way ethereal oils are removed from it. These oils are used in chemical industry.

Energetic requirements of flour drying were one part of this solution. With artificial drying of agricultural products heating oils or gas are used as a source of energy. With aim to eliminate the use of these sources a furnace for the burning of sorted wood fraction was finished. Offtake of combustion gases is conveyed through drier and whole regime of heating is connected to automated regulation of drying.

Tree foliage was recently unused raw material. Modern logging technologies make possible to utilize also this material. The results of experiments have shown that flour produced from tree foliage can be valuable feeding addition with specific, effective substances for additional feeding of farm animals and also forest game.

# MECHANIZATION OF FOREST OPERATIONS UNDER NEW ECOLOGICAL CONDITIONS

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FDC: 307: 907

Present ecological situation and worsening health state of forests affect principally also the look at further development of technization. Though this status is in decisive range the result of environment pollution by pollutants emitted from industrial plants we cannot disregard also damaging of forest ecosystems by forest machinery. It regards the pollution of natural environment by waste products (exhaust gases, fuels, oils) and also damaging of soil, trees and health of people due to machines being used. It will be necessary to develop and manufacture machines which would be more adapted to biological aspects, machines lighter, more mobile in forest environment, and more reliable.

For the improvement of maneuverability and driving of machines it is necessary to introduce electronics and automation. Constructional and technical parameters of machines used in forests affect significantly their suitability for particular natural conditions and methods of management of forests. Greater ecological and economic damages can be caused also by wrong utilization of machines suitable in other aspects. In this aspect man plays decisive role. Therefore it will be necessary to pay greater attention to relations of man-machine-nature in their interactions.

Changes in used machinery and technologies will be caused also by altered methods of management of forests. Instead of logging purposeful regeneration and tending of stands on restristed areas with corresponding concentration, great portion of timber will be logged under the conditions of salvage, sparse loggings over the whole territory of forests. It requires new, distinguishing solution of the problems of access to forests with the use of complex information system and computers.

Without suitable machinery and technology it will be impossible to ensure the management of forests under altered ecological conditions. Forest management must be in the aspect of mechanization put on the level of other branches, while biological principles of management in forests will remain the most important.

# SOME CONSIDERATIONS ON FOREST STRIP ROADS UNDER DIFFERENT TERRAIN CONDITIONS IN JAPAN

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## SUMMARY

FDC: 663.25: 663.26: 383.2: 923.4: (23): (52)

The following facts were found from this research on forest strip roads built in slight and steep terrain areas in Japan: (1) there was a great difference in building cost in areas with steep slope between forest roads and strip roads. (2) The strip roads built in areas with slight slope were comparatively expensive because of the increase in constructing cost due to drainage and ballasting. (3) It was considered to be able to manage economically in small scale private forest in good combination with the narrow strip road and small sized machines only by one man worker. (4) To pull up an obstructive tree, an efffective method was confirmed.

Keywords: Forest strip road, productivity, building cost, private forest, different terrains

## INTRODUCTION

It is not easy to increase expensive forest roads in Japan, because the terrain conditions are steep and difficult. Therefore, most Japanese private forest owners have to accept the lower cost road like strip roads without regulations. Some of important questions are dealt with in this paper, that is, the difference of building cost between different terrains, how to build the narrow strip road in width and economical yarding cost.

## RESEARCHED METHOD AND MATERIALS

To obtain a lot of researching materials, the author carried out questionnaires about the total length of the strip road, its constructions and building cost to private forest owners through the local government in the whole country, and besides some informations were also gathered from the general plan, plans and profils for earth work, building costs,records of road maintenance and yarding practice in Shizuoka prefecture.

# PHYSIOLOGICAL CONSIDERATIONS FOR QUALITY SEEDLING PRODUCTION IN FOREST TREE SPECIES

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FDC: 232.411.3: 181.2/.3

Artificial regeneration of existing forests and creating a new ones need nursery produced plants. As plantation success depends upon the outcome of an interaction between the stock planted and the site conditions, therefore, planting stock characteristics are always a determining factor. These characteristics reflect the quality of the seedling and are site specific. The attributes that comprises quality seedling may vary depending particularly on the environment conditions to which seedlings will be exposed following outplanting.

In many countries of the world, foresters utilize the morphological attributes as the only criterion of quality seedling. Although morphological characteristics are important for any reforestation program but are insufficient indicators to give seedling performance after outplanting. The physiological attributes of the seedling like frost hardiness, root growth potential, carbohydrate reserves, drought resistance, internal water status etc. play a vital role in the establishment and after growth following outplanting. The paper overview the role of these attributes and discuss the means of their possible improvement at the nursery stage.

# HELICOPTER THINNING SYSTEM WITH AN AIR-PORTABLE SAWMILL

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FDC: 376: 832.16: 666: (23): (52)

Recently, a new venture of helicopter logging has been carried out in Japan in reducing the logging cost of thinned logs. It is the helicopter thinning system with a newly-developed small sawmill which can be flown to the logging site in the mountain forest by helicopter and produce lumber from thinned logs of the Japanese cedar (Cryptomeria japonica) and the Japanese cypress (Chamaecyparis obtusa) in a one-man operation.

In this system, the thinned logs cut down in late summer or fall are being left in an untouched condition for several months till winter with their leaves only around the tops of the trees in order to dry the stems naturally. They are prehauled by a small prehauling machine and/or yarded by a small yarder to the sawmill in winter. The lumber in pillar or board form produced by the sawmill is flown by helicopter to the landing area adjacent to a road, and transported by truck directly to the lumber market.

The sawmill has an eight-meter-long main beam on which logs are lumbered. It weighs 1.4 tons and can be taken in three sections, of which the maximum weighs 1 ton, when transported to the forest by helicopter. It has a cemented-carbide-tipped twin circular saw and can produce fine lumber of 45 to 136 mm in width and of 2 to 4 m in length from logs less than 25 cm in diameter. As the lumber produced by the sawmill has very good surfaces, its sales price becomes three to four times higher than leaving the uncut logs as they are.

This new system has been tested at several private man-made forests in central Japan since January of 1988 with two kinds of helicopters capable of lifting 1,300 kg or 900 kg per turn. The former helicopter was used for transporting the sawmill, the prehauling machine, the yarder and so on. The latter was for transporting lumber of which the lot volume was set around one cubic meter weighing 750 kg in average per turn.

The cost analysis revealed that through selection of an adequate kind of helicopter, organization of an adequate operation crew, and control of an adequate lumber lot weight per turn, this system can become profitable because a helicopter would transport only the lumber, with residue, which amounts to over 50 percent of the total log volume, remaining in the forest.

# DELIMITATION OF CABLE YARDING AND TRACTOR WORKING AREAS IN WOOD SKIDDING ON THE BASIS OF WORK STUDYING

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FDC: 662.3: 30--015.5

Slovenia is a republic which is situated in the north of Yugoslavia and covers the southern Alps and prealpine mountains. It stretches from the northern part of the Adriatic Sea to the plains along the Hungarian border. Stocking degree of the country amounts to 51% (1.0 million ha of forests), 1/3 of which are state forests, the rest being private ones. Coniferous trees prevail (56%) - the Norway spruce, the European silver fir, the pine and the European larch yet among deciduous trees, the beech and the Common oak are the most frequent tree species. 3.9 million $m^3$ of timber, 1.5 million $m^3$ of conifers and 2.4 million $m^3$ of deciduous trees are felled annually. The technologies and methods of forest utilization applied in state forests are by far more advanced than those in private forests. The technology of assortment preparation in central mechanized yards is the one which is most frequently applied in state forests whereas in private forests, assortment preparation is performed in the forest. The use of tractors prevails among the mechanized wood skidding ways. Only 6% of wood are skidded to roads by means of cable yarding, 80% thereof uphill. The use of cable yarding systems in Slovenia evidences a positive trend.

An inductively-deductive approach has been chosen for the analyzing of the most important factors in delimitation of cable yarding and tractor working areas in wood skidding. All the important relations which affect the total wood skidding costs have been defined. These are: performance in relation to working conditions, costs in relation to work organization, machine type and working conditions, the influence of the forest stand upon performance and costs and the influence of forest road construction. Working conditions have been simulated by applying the FOROPERA (IBM XT/AT) computer program which enabled the calculation of wood skidding and forest opening costs for each combination. The results of the simulation have been analyzed by means of standard statistical methods and the most characteristic relations in tractor and cable yarding skidding have been established.

The most influential factors as regards total wood skidding costs are forest stand characteristics and the effect of forest accessibility. As for the forest accessibility, the forest road and secondary thoroughfare density has the greatest effect, especially in solid ground where construction costs are high.

The FOROPERA program offers the possibility of testing different working methods in wood skidding and establishing of costs for individual production phases. The program is primarily intended for research work and thus represents a powerful means for the studying of new solutions in the process of forest utilization.

# AN APPROACH TO THINNIG METHODS AND RELATED MACHINERY

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FDC: 242: 307--015.5

Simulation modelling methods, along with on-site experimentation, have, of late, gained in moment in efficiency estimates for thinning methods and the related machinery. These methods, it is to be noted, have already been practiced during 60-ies in a number of countries as Sweden, Canada, while the earliest publications in this country appeared much later. Our overall logging behind in computer literacy and predominance of empirical methods in forestry research have here been the primary reasons.

The application of simulation modelling methods involves the following three principal stages:
- constructing forest stand (machine use environment) mathematical model;
- formalizing working cycle operations, constructing a mathematical model for machine activity;
- computer-aided analyses of the model obtained.

The data, thus obtained by way of treating the body of information contained in the Latvian SSR forest stock data base.

The present method for research on machine performance in thinnings permits prolonged and resources-consuming on-site experimentation to be replaced by mathematical modelling. The precision of modelling is no less than that achieved in on-site experiments.

Any characteristics may easily be altered with mathematical modelling, thus enabling more complete and all-round analyses to be performed.

Simulation modelling methods provide for definite goal-oriented alterations to be made on machine characteristics, i.e., formulation of problems for optimizing machine characteristics as well as a search for optimum method-related decisions.

Ecological assessement of the thinnings machinery and related methods has remained outside the scope of the present paper. The existing level of knowledge in this respect is inadequate for the raid criteria to be adequately formalized and incorporated in mathematical models. This is the task for future studies.

# REORGANIZATION IN SAWMILLS: EFFECTS ON THE QUALITY OF WORKING CONDITIONS AND JOB SATISFACTION

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FDC: 832.14: 302

Towards the end of the seventies, an ergonomical study was carried out for the first time in Italy concerning the sawmills of the southern alpine area by a group of researchers from the "Istituto per la Tecnologia del Legno, Consiglio Nazionale delle Ricerche" and the "Dipartimento del Lavoro" of the University of Trento. The aims of the study were the improvement of working conditions and the consequent improvement of work efficiency to be accomplished by means of a far-reaching reorganization programme of the mill structure.

The organizational restructuring then suggested by the researchers and the subsequent introduction of new production technology and different ways of selecting and training personnel seem to have considerably changed the work situation.

It was deemed to be important to carry out a comparative study with regard to the past in order to evaluate the psycho-social effects of the changes that were introduced. This study was performed on the sawmill that was identified as being the most representative according to a set of parameters. Here the workers moved from a type of job that involved tasks that were individual but closely interdependent (especially for the workers in the sawing shops) and which required high levels of decision making to a kind of job that is richer but prevalently and closely linked to the technical nature of the new machinery used. The study hypothesized that this change had had a noticeable effect of mental overloading, of isolation from others and a tendency toward a drop in the level of satisfaction and job involvment.

The results of the study confirm these hypotheses to a large extent. However, the levels of satisfaction and involvment remain high as a result of the kind of management that runs the sawmill and which has adopted a special system of incentives and effective professional rewards.

# THE FOREST MACHINE OWNER'S WORK SITUATION

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FDC: 302: 644.6

The development in Swedish forestry enterprises indicates increasing annual felling. The degree of mechanization is also rising. In spite of this, the total number of forest machines is likely to decrease. This implies larger annual volume per machine, which can be obtained either by increased productivity or extended time use or both.

This is results based on a study carried through in three steps. First, information was collected from Swedish forest companies on all machinery, corresponding ownership and total logging volume in 85/86, plus a forecast for logging season 90/91. Second, a questionnaire was sent to some 500 machine operators/owners dealing with the physical and psychosocial working conditions. Finally, after merging the responding machine owners into four groups, 10 representatives of each were visited and interviewed in order to strengthen the statistical data.

Logging machines are owned in three principle ways in Sweden. Either by the forest enterprise, by an individual employed worker or by a logging contractor. An increasing number of the forest machines are owned by private persons. For the logging season 90/91, no more than 30 pct are expected to be owned by the forest enterprises themselves in comparison to 35 pct in 85/86.

The most common business structure for the private forest machine owner is a single-machine company with commitments only to one forest enterprise. This increases the contractor's chance to work under stable conditions. Still, some of them think this restricts the open market forces.

More than half of the machine owners have seriously considered quiting. Several of them claim, that the work intrudes too much into family life. 75 pct of those who have had plans to quit, work more than 60 hours per week in comparison to some 30 pct of all machine owners. Nevertheless, 25 pct of the machine owners have had serious plans to expand.

The contractors suggest that one important task in the future will be to improve the agreements with the forest enterprises, both in terms of length and remunaration.

# DELIVERY SALES IN THE HARVESTING OF TIMBER IN THE PRIVATE FORESTS OF FINLAND

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FDC: 756: 923.4: (471.1)

The main forms of selling timber in Finland are delivery sales and standing sales. In the case of delivery sales, the forest owner is responsible for harvesting the timber, in standing sales the buyer. In delivery sales, the timber is also harvested mainly by the forest owner or by some member of his family.

The share of delivery sales in the private forests diminished from the end of the 1960's for more than 10 years. At the beginning of the 1980's, however, the direction of the development changed so that the timber volume of delivery sales increased from 6,6 milj $m^3$ in the logging season 1980-81 to 13,3 milj $m^3$ in 1984-85. Correspondingly, the proportion of commercial cuttings in the private forests increased from 21% to 35%. The partial exemption from taxes given to logging work in delivery sales, the changes in the price recommendations of timber in favour of delivery sales, and the intensifying of the instruction and training work of the forest owners are probably the most important factors which have affected the direction of this development.

After the logging season 1984-85, the amount and the proportion of delivery sales have decreased to some extent. The author presents different development trends of delivery sales, wood harvesting techniques used and economical aspects.

# PLANNING AND CONTROL OF SORT YARD OPERATIONS THROUGH SIMULATION

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FDC: 325: (711)--015.5

Network simulation was used to model and study log sortyard operations common to the coastal region of British Columbia. The model, written using the simulation language SLAM II/PC, was developed to assist with sortyard management and design efforts. The program incorporated operational modules to facilitate simulation of different sortyard configurations and operating capacities. An accompanying economic analysis program was developed using Lotus 1-2-3® to derive pertinent cost data from generated simulation results.

The developed model was tested and verified for a small capacity (< 75,000 $M^3$) log sortyard operated by the Greater Vancouver Regional District (GVRD) in Vancouver, BC. Time and motion study data for the sortyard were compiled, analyzed, and incorporated into the model. Using the data, the sortyard simulation program was verified and found to accurately model this small capacity sortyard. Efforts are currently under way to verify the model for larger capacity sortyard operations.

# RECENT ACHIEVEMENTS OF OPERATIONS IN CHINESE TROPICAL FORESTS

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## SUMMARY

FDC: 31: 376: 233: (213)

The tropical forest of China is distributed mainly in Hainan, the newly established (1988) province and the second largest island of China. There are thousands of tree species of which 460 or more produce merchantable timber. At the beginning of the Republic in 1949, the area of natural forest was about 863 thousand hectares. At present it has been reduced to about 400 thousand hectares.

In the practice of logging and regeneration of the tropical natural forest, we have tried many methods: (1) clearcutting followed by tractor skidding or cable yarding, and natural regeneration; (2) cutting by diameter and regeneration by natural seedlings and assisted by planting; (3) selective cutting by multiple diameters according to different species. The last method will result in a stand which would recover the original conditions in only about 13 years.

To get economically the highest quality of tropical timber, such as Homalium haianense, Litchi chinensis, and similar species that are distributed in a widely scattered way, the author suggests that helicopter logging should be considered.

Key words: tropical forest, exploitation, conservation, helicopter.

# WOOD FUEL SUPPLY STRATEGIES

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FDC: 831.1: 662

Wood fuel supply strategies to provide wood fuel to three sizes of combustion plant (1.5 MW, 6.0 MW and 30.0 MW) were developed. These were based on 3 sources of wood fuel (Whole conifer trees from early thinnings, whole hardwood trees from thinnings, and forest residues from conifer thinnings and clearfell) and 3 wood fuel harvesting systems (whole tree comminution, residue harvesting, and integrated harvesting systems). A series of harvesting models were constructed with the aid of a Harvesting Decision Support System. These were linked to a number of storage and transport options to provide 24 supply options on which to build wood fuel supply strategies.

The lowest delivered fuel costs, from integrated harvesting systems in conifer clearfell, are £1.17/GJ, £1.31/GJ and £1.54/GJ respectively over the 3 plant sizes. Integrated harvesting systems offer the greatest potential for cost effective harvesting of wood fuel in conjunction with conventional forest products from the stemwood.

Residue harvesting systems produce wood fuel in the delivered price range of £2.18/GJ to £2.33/GJ. They are the most appropriate methods for the introduction of wood fuel harvesting into present shortwood systems if improvements to the technology of comminution can be made.

Whole tree comminution in hardwood thinnings gives supply costs from £1.79/GJ. Whole tree comminution for early conifer thinnings gives costs of £2.32/GJ to £2.40/GJ.

# APPLICATIONS OF SMALL-SCALE TECHNOLOGY IN COMMERCIAL THINNING OPERATIONS IN SWEDEN

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## SUMMARY

FDC: 66: 241

The high costs of commercial thinning operations in small-dimension stands often challange the profitability of first thinnings. The application of small-scale technology in thinning operations is presented. Results from simulations of logging systems indicate that the use of small-scale technology can be cost competitive with the use of the most favoured large-scale approach in a small-dimension stand. Consideration of moving costs and the future development of the residual stand, as well as the machine and labour costs, are important factors which can favour the use of small-scale technology in an analysis of logging costs.

Keywords: Commercial thinning, small-scale technology, logging cost

## INTRODUCTION

The purpose of this paper is to present some of the applications for small-scale technology in commercial thinning operations in Sweden. The results of an analysis of the costs associated with a number of logging systems are presented. Along with machine and labour costs, the implications of the cost for moving between tracts and the net present worth of future wood production losses due to thinning operation are addressed.

The analysis has been carried out to evaluate the costs associated with logging systems using small-scale technology, and to compare these with the application of the presently most favoured large-scale technology in commercial thinning operations. The analysis was confined to compare logging costs and does not directly address questions related to profitability.

Small-scale technology has been described in the following terms (Ager 1987):

- low level of investment resulting in low unit capital costs;
- unsophisticated technology which is easy to learn and apply;
- ease of maintenance.

# A COMPARISON OF TIME STUDY TECHNIQUES IN FELLER PRODUCTIVITY STUDIES

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FDC: 305: 32

In Ireland the widespread use of systematic thinning systems has contributed to large scale windthrow damage. Consequently, in many parts of the country, rack and selective thinning systems have replaced systematic thinnings at first thinning stage. The benefits of the former systems, in terms of lower windthrow losses and improved silviculture, have to be weighted against their higher harvesting costs, arising from increases in marking, brashing and supervising costs, and a reduction in feller productivity.

A study was carried out to quantify how feller productivity is influenced by the following thinning systems: line thinning, chevron thinning, and rack and selective thinning. Reductions in productivity of up to 30 percent were found when the rack and selective system was compared to the line thinning system (see Table 1).

Table 1: Mean Volume, Mean Time, and Mean Productivity for the Thinning Systems studied

| Thinning system | Mean Time per tree (min) | Mean Volume per tree ($m^3$) | Mean Productivity ($m^3$/hr) |
|---|---|---|---|
| 1) Line thinning | 4.04 | 0.070 | 1.04 |
| 2) Chevron thinning | 4.22 | 0.069 | 0.98 |
| 3) Rack and selective thinning | 4.13 | 0.055 | 0.80 |

This drop in productivity was explained by the significantly lower volume of the felled trees in the rack and selective system. In addition, the less favourable working environment associated with this systems outweighs any advantage the smaller tree size may offer the feller with regard to cycle time.

Two time study techniques were used in this project. The authors recorded actual times, whereas Forest Service personnel used standard work study procedures which included performance rating. A detailed comparison was made of the results obtained by these two methods. While the trends in the results were similar, the actual values differed considerably. It was found that the following factors were important in explaining the differences in the results: rest allowances vs. actual rest times, volume calculations methods, and the use of performance rating.

Any presentation of productivity information should therefore always include a description of the time study techniques used during data collection and analysis.

# SMALL TERRAIN MACHINES FOR FORESTRY PERFORMANCE, REQUIREMENTS, DEVELOPMENT

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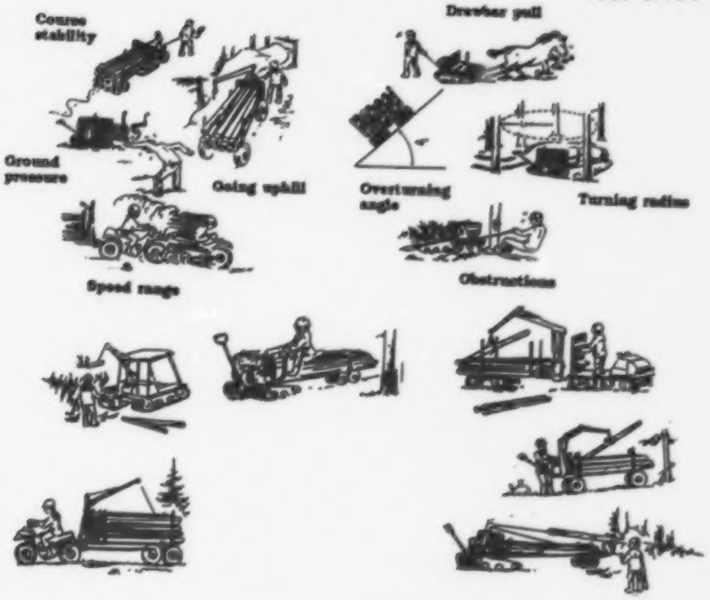
FDC: 377.4--01



## SUMMARY

The interest in small size off-road vehicles, primarily for use within Swedish private estate forestry, has increased steadily over the last few years. Normally, lumber transport is the most demanding kind of off-road driving. A number of small size off-road machines have been examined regarding off-road properties, transport capacity and ergonomic properties. To examine these properties some tests were conducted. The tests included ability to pass obstacles, overturning angle, course stability, turning radius, drawbar pull, speed variability, maneuverability, ability to go uphill and ground pressure. On the basis of the tests, a list of requirements has been set up. Finally, it has been judged what kind of forestry work each machine is best suited for.

Keywords: Small-scale forestry, small machines, off-road transportation, function test

# THE PROFITABILITY OF FOREST OWNING AND ITS ACCOUNTING BASES

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FDC: 923: 671

The profitability of forest owning has been affected not only by decreasing roundwood prices, but also by growing artificial regeneration costs, which have emerged as a tough profitability evaluation requirement. In addition, an increase in the forest taxation has inspired a furious discussion. On the other hand, the debate on forestry management has emphasized the needs of the national economy and especially the supply of roundwood, and has often ignored the profitability of forest ownership in terms of explicit observed and planned returns on investment (ROI). Contemporarary turbulent changes in the financial markets have created instruments, available for private forest owners, to increase the rate of return by accepting higher risks and thus to benefit from lucrative financial businesses. Economists in the forest industry might admire the ROI of, say, modern paper mills, and blame the company forests' slow and lazy money. The recent competitive strategy approach also emphasizes optimal allocation of working capital. The development of portfolio management with modern risk aversion and optimal allocation models allows profit maximization calculations in complicated environments with various assets and liabilities.

The dilemma of the real profit and loss of a forest enterprise has been tackled by developing the accounting frames with new proposals for, e.g., reservations and depreciations. The information requirements have been related to the forest stand record of the forest management plan provided by the advisory organizations. The developed forest calculation software, which also includes growth functions, have been applied for constructing ex post and ex ante entities from differences of forest capital to interactive planning. Developments are aimed at the forest owners' decision support systems (DSS). ROI calculation cases represent forest departments from industry, forestry boards and private forest owners. Finally, the influence of the profitability impact of liquidity and raw material source opportunities as well as negotiation power, in the strategy of a forest industry enterprise has been analyzed and discussed.

# BARKING IN THE ALPINE ENVIRONMENT: PRESENT STATUS AND PERSPECTIVES

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FDC: 323.5: (23)

The wood with bark which from the forest reaches directly the sawmills is still an exception on the southern side of the Alps. In fact, apart from a few concerns which are provided with a steady barker on the yard, in almost no case can the sawmills (which in general are small or medium-small) amortise the investment required for this kind of machine.

There are further reasons (which are related to the inadequate forest mechanisation and to the discontinuity of the production process in the forest) why barking is still performed in the forest, often manually at the felling site. The negative consequences of this situation (also on the overall productivity of the whole production cycle) can be easily imagined, given the low productivity of this operation.

The four traditional barking systems which are the most used on the Italian Alps are analysed: axe barking, barking with iron, barking with a special, locally manufactured tool, barking with plane on chain-saw; their productivity, also as a function of log diameter, as well as their labour cost, are compared.

These working systems are then compared to a mechanised system based on a prototype of an innovative mobile barking machine, which has small dimensions and is also suitable to the difficult conditions of the alpine environment.

The conclusion is that a rational improvement of logging operations will require mechanisation of barking; however, in order to reach an important increase in the productivity of the whole production cycle and lowering of costs, it will be necessary to improve the overall organisation of the forest working cycle, by balancing the introduction of suitable mechanical equipment with appropriate sylvicultural operations and with the necessary political management of the forest itself.

# SMALL-SCALE SAWMILLING AND WOOD PROCESSING NEW STRATEGY FOR PRIVATE WOODLOT OWNERS

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FDC: 82: 923.4

Technological research in the private woodlot owner's sector, is historically carried out with the purpose to reduce costs in forest operations. Now time has come to develop the alternative way - increase of product values. One possibility is sawmilling and further processing of wood by using small-scale technology.

Small-scale sawmilling has become more and more frequent in Norway, Finland and Sweden during the last decade. Two co-operating factors can be identified to explain this process:

1. Serious economical problems in the agricultural sector, forcing people to create new ideas for their living and survival.
2. Technical improvements in the circular saw, providing one-man operation and a flexible work situation, fit well in small-scale forestry and specially for farmers combining agriculture and forestry.

The basic strategy in small-scale sawmilling must be to serve the local market and to find niches where the sawmill industry cannot compete. Production of lumber from certain species for special use may be one such niche. Special qualities, dimensions and lengths may be another.

The paper gives a brief review of technical applications, work organization, work environment aspects and economy. Furthermore, there will be given an exposé over the next step - wood processing and design of wood products under small-scale conditions.

There are several creative practical cases presented, which indicate a high economical potential.

# EXPLOITATION DES PREMIERES ECLAIRCIES RESINEUSES SITUEES SUR TERRAINS EN FORTE PENTE

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FDC: 377: (23)

Depuis 1945, presque 2 000 000 hectares d'essences résineuses ont été plantées en France, dont environ 20 % sur des terrains qui dépassent 30 % de pente, seuil d'accessibilité pour les machines de débardage de type porteur.

Dans la plupart des cas, les travaux de première éclaircie ont été effectués, et même de deuxième éclaircie dans les peuplements les plus anciens. Généralement ces opérations ont pu être pratiquées dans les zones de faible pente (< 30 %) lorsque des routes forestières existaient. En revanche, il existe encore de très nombreux peuplements où les éclaircies n'ont pas pu se faire à cause d'un relief plus difficile avec des pentes fortes à très fortes et où le débardage avec des machines porteuses est impossible.

Le Centre Technique du Bois et de l'Ameublement a conduit plusieurs expérimentations avec des machines qui pouvaient réaliser le débardage de petits bois sur des pentes prononcées comme par exemple:

- le tracteur chenillard FIAT-ALIS
- le débasqueur CEMET 338
- la machine VIMEK
- le cable TIMBERMASTER

Les volumes réduits des tiges exploitées et les petites quantités récoltées à l'hectare, expliquent les faibles rendements obtenus, pour une des opérations les plus difficile à accomplir en forêt.

# HARVESTING IN THE MIXEDWOOD

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FDC: 31: 66: 461/462: 228.3

## SUMMARY

This report discusses the preliminary results of a mixedwood harvesting study being undertaken in Alberta. The objectives of the study are to determine the costs, productivity, and effectiveness of using different harvesting equipment and systems to protect the white-spruce understorey while harvesting the mature aspen and conifer overstorey. Observations from studies completed to date indicate understorey damage is most severe following the extraction phase, and can be reduced through planning, equipment selection, supervision, and operational practices. Preliminary production studies indicate felling production decreased when residuals were protected because the equipment manoeuvred around residuals and spent more time bunching. Skidding production also decreased because of longer skidding distances associated with a designated skid-trail layout.

Keywords: Mixedwood harvesting, White spruce, Aspen, Skidding, Alberta.

# ERGONOMIC STRESS EXPERIENCED BY THE TRACTOR DRIVER DURING ROPE EXTENSION,BOTH WITH AND WITHOUT A ROPE DRIVE-OUT MECHANISM, AND THE CONSEQUENCES FOR SECONDARY ROAD NETWORK.

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## SUMMARY

FDC: 302: 377.44: 686.33

This paper discusses some components of the secondary road network planning,especially the distances between the thinning strip roads.The distance between the strip roads is important for the planning of the complete transport system in the forest area.There are many components,which linked together this area. One of the important aspects of the planning is the physical strength needed to pull out the cable from the tractor winch. The stress of this work for tractor drivers was tested and a recommendation was presented for the distances of cable to be pulled out in respect to the terrain conditions and to the stress for drivers.

Keywords: Skidding of wood,stress of tractor drivers,length of winch rope, distance between thinning roads

# DECOMPOSITION DYNAMICS OF ALIEN AND NATIVE PLANT LITTER IN A MONTANE HAWAIIAN RAINFOREST

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## SUMMARY

FDC: 114.351: 181.34: 181.41: 176.1 Acacia koa 176.1 Metrosideros polymorpha: 176.1 Passiflora mollissima: (969)

The structure and functioning of koa (Acacia koa) and koa-ohia (Metrosideros polymorpha) forests between 1,200 m and 1,800 m elevation on the island of Hawaii are being threatened by banana poka (Passiflora mollissima), an aggressive alien vine from South America. To assess the alien's impact on a key nutrient cycling process, we studied the decomposition dynamics of poka and selected native leaf litter, singly and in mixture, using litter bags. Less than 5% of the initial dry mass of the nutrient-rich poka leaves remained after 140 days on the forest floor. Decomposition was slower for the nutrient-poor and sclerophyllous native leaf litters -- koa, 50% left; ohia, 60%; and tree fern, 85%. Of the litter quality indices examined, the ratio of initial lignin:initial ash was best correlated with litter disappearance ($R^2 = 0.90$). Decomposition of tree fern fronds was not correlated with any of the litter quality indices. Poka in mixture with koa or ohia leaves speeded decomposition of the native litter.

# COMPARATIVE STUDY OF TWO OPERATIONAL TRANSPORT SYSTEMS USING LOGS OF VARYING LENGTHS

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FDC: 665: 375.4/.5

This work developed an alternative primary transport system for Eucalyptus spp plantations in Brazil. It shows the advantages of log length increase and the good possibilities for mechanization improvement over the next years.

Two different lengths were studied: 2.20 meters and 4.40 meters. The length around 2.00 meters is greatly utilized in Brazilian logging systems. A team of 4 trucks (6 x 2) transported 2.20 meter logs and the 4.40 meter logs were transported to strip roads by tractor (4 x 4) connected to a trailer. The average distance was 300 meters. The cost of transporting 1 ST (1 piled up cubic meter of logs) by truck is US$1,66 and by tractor plus trailer is US$0,62/ST.

# THE DEVELOPMENT AND POSSIBILITIES FOR SMALL SCALE FORESTRY IN SWEDEN

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FDC: 923.4: (485)

At the end of the second world war there were more than 290 000 holdings in the non industrial private forestry in Sweden. Nearly all of them were managed in combination, agriculture-forestry. The selfemployment in forestry was nearly 100 per cent. Moreover, an important part of the work in largescale forestry was carried out by their private owners.

A very large change has taken place since then. A strong demand för labour-force in the industries and in the servicesector led to greatly increasing wages. This forced agriculture and forestry to a strong rationalization and mecanization of the work. Trough plant breeding and artificial manuring a considerably higher yield per hectare could be obtained.

All this led to a reduced need for manpower in agriculture and forestry and a diminished need for agricultural area. On many small combined holdings the agriculture had to be discontinued since it didn't give enough income to the owner and his family. Some holdings were sold and, often with helps of the state, put together into bigger holdings. But most of the holdings have been taken over by the children, together, and then principally used for hunting and recreation.

The development has led to the situation that we today have a very heterogeneous group of non industrial private owners. Through purchasing and uniting holdings we have today less than 240 000 holdings. About 60 per cent of the holdings are now pure forest holdings (less than 2 ha of agriculture land) and they correspond to about 55 per cent of the private forest area. The average forest area of the holdings has increased from barely 40 to 45 hectares. On 28 per cent of the holdings there is more than one owner (family) registered. Due to this, the number of forest owners has increased and there are today more than 400 000 in spite of the decreasing number of holdings. The average age of the owners is very high. On 28 per cent of the holdings the owners are more than 65 years old. The owners reside all year round on only 64 per cent of the holdings. On a great number of the holdings the owners and their families work and have their principal income outside the holdings. On a large part of the holdings the owners hired help to perform the work in the forest. But there are still owners who are selfemployed in the forest work and the selfemployment has increased during the last 15-year period. Selfemployment in cutting was, for example 34 per cent in the logging season 83/84 and in silviculture work the selfemployment was between 60 and 70 per cent in the most common works in 1984.

This increase in selfemployment has happened in spite of many unfavourable circumstances for the small scale forestry such as modest research and development of methods and machines, a price setting of wood that has counteracted selfemployment, a dumping price setting on measures performed using large-scale techniques. Even tax-legislation and increasing state bureaucracy have probably counteracted selfemployment or work under own management.

The factors that have probably contributed the most to an increased degree of selfemployment are:

1. Decreasing profits from the agriculture work which force the farmers to increase the income from forestry.
2. Increasing costs and administrative difficulties in getting forest work performed by others.
3. Increasing demands from the State authorities on increased cutting and good silviculture.
4. A better profit in the forestry and through this an increased trust in a good future in forestry.

The policy that the Government will conduct is of the greatest importance for the future development.

- The present economic policy with, among other things, a high inflation and high income and capital taxes implies that persons with capital resources want to place their capital in stable and as safe investments as possible from a tax point of view. Forest is one good possibility and the prices of forest holdings have today reached such a high level that the interest on the buying capital is only two to three per cent. Persons who want to start up as selfemployed forest owners but have to borrow nearly all the capital cannot manage the interest that the bank requests and at the same time support their families. The economic policy must be changed.
- The regional policy today favours the big cities at the expense of the countryside. The net stream of money principally goes to big cities and regional centres and employment will be favoured and created principally in these places. The regional policy must therefore be changed so that the countryside and therewith the small-scale forestry will not be treated unfairly.
- Research and development in the small-scale forestry are at present of relatively modest proportion compared with the large-scale forestry. An increased concentration in research and development is necessary for a better development of small-scale forestry in the future.
- Discontinuation of agriculture in certain part of the country may probably not be pushed so hard that the whole infrastructure will be risked and the people move from the district for this reason.
- Administrative regulation may not be forced so hard that people lose their interest in private management.
- Large-scale forestry may not unduely be allowed to compete with the small scale forestry with e.g. incorrect pricing of wood and service.
- Research information and extension should be established so that the message will reach the private forest owners and will suit his demands.

# COMPUTER APPLICATION FOR ENVIRONMENTAL IMPACT EVALUATION IN THE OPENING-UP PLANNING PROCESS

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FDC: 686.3: 907--01

Access development in mountain forests under difficult terrain conditions is presently confronted with ever more varying restrictions integrating engineering, financial, social and environmental concerns. In view of the changing demands on mountain forests and the uncertainty of their future, general access development in these regions will have to be planned very carefully. The methodology and techniques of such planning procedures require further development. The integrated planning process can permit not only great adaptability to local conditions but also the identification and inclusion of key points for opening up. In addition, it must develop a large number of aids for decision-making in the evaluation and selection of alternatives in relation to local circumstances.

A particulary interesting part of the opening-up planning process for the road network system is facilitation in generating alternative routings under the various constraints influencing the location of routes in forest areas. This paper attempts to incorporate environmental data, particulary terrain sensitivity to disturbance, into a computerized route location and evaluation system for alternatives.

The main features of the design process for the system, in simplified terms, include: procuring all relevant planning information and documents; zoning critical cites and identifying major control points; generating alternative routes based on a path algorithm; computation of the degrees of goal performance; and evaluation and comparison of the alternatives. As a case study this system was applied to the road-network planning for the private forest "Schönsee-Drechselberg" consisting of 210ha in east Bavaria.

The system, in its present form, can identify critical zones or terrain types which have been classified according to the severity of engineering difficulties or degree of terrain sensitivity based primarily upon landform attributes, drainage barriers and soil conditions. The routing procedure presented here does not promise an optimal route, since it is based on the sequential examination of local data. However, it does allow flexibility in route evaluation and selection by producing alternate routings under different sets of constraints, taking engineering and environmental estimates into account.

# THE EFFECT OF TRACTOR LOGGING ON PHYSICAL PROPERTIES OF FOREST SOIL AND THE GROWTH OF PLANTED SEEDLINGS

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FDC: 375.4: 114.11: 462

The height-growth of planted seedlings and soil conditions were investigated in two controlled experimental areas and four study areas.

On the skid trail in a gentle slope on which the surface soil was not removed, the influence of soil compaction by logging tractors on the growth of planted seedlings and soil physical properties was very slight during the first growing season. In the 4-7 years following the compaction, height-growth of planted seedlings and soil conditions recovered to the same level as that in undisturbed areas.

On the bare skid road constructed by removing surface soil of 0.3-2.0 m depth in hilly logging areas, influence of soil compactions and disturbance was great during the first growing season. In the 4-7 years, the recovery from the decrease in height-growth of planted seedlings and the bad soil physical properties was scarcely improved.

Fertilizing was effective for preventing the growth reduction of the seedlings planted on those road.

# ERGONOMIC WORKPLACES AND THEIR ACTIVITIES IN THE FORESTRY OF THE CZECH SOCIALIST REPUBLIC

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FDC: 302: (437)

The methodological basis for the activities of ergonomic workplaces within state forests organizations in the Czech Socialist Republic is formed by unified methods of a system of forestry ergonomic databank (ERGOBANKA). These methods are being created at our Division of Forestry Ergonomics, Dept of Forest Harvesting, Faculty of Forestry, University of Agriculture in Brno within the framework of its research activities. The methods are intended for use in testing and assessment of forest workers (technical activities, workers' occupations) in terms of health condition, and both psychological and ergonomic aspects.

The enterprise school of the South Moravian State Forests at Slavkov near Brno has recently established an ergonomic division which is concerned with the choice of suitable workers for the profession of timberjack in operational conditions. There were over forty applicants for the job examined here during 1989.

Substantially more extensive ergonomic measurements are being carried out in ergonomic laboratories of the forestry professional apprentice centres and vocational schools. The labs have been established in seven of the total of 13 centres of this type. The measurements have been run under our methodological leadership for three years, yielding the data from as many as almost 1000 apprentices up to now.

Last year, the input information had to be modified in connection with shifting all the aggregative calculations onto the computer with the results being forwarded back for use at the apprentice centres.

Our ergonomic research is rather extensive with part of the results being successfully utilized in forestry practice.

# A RESULT OF EXPERIMENT ON THE EFFECT OF NOISE ON CHAINSAW OPERATOR.

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FDC: 362.7: 302--015.22

A forest worker who uses a chainsaw everyday has easily a temporary hearing loss by being exposed to the large noise. However, he seems to recover from the temporary hearing loss in a short period of time. The degree of the damage differs at a center frequency of the sound that he hears. Being exposed to the large noise for a long period of time, a worker may lose his hearing ability permanently. Therefore, we must pay special attention to the noise hazards to hearing. The measurement was carried out as following procedures: (1) a person was selected from five chain saw operators who has similar hearing ability; and (2) a change in his hearing ability was measured by an audiometer and recorded four times a day.

By the work in the morning, his auditory acuity was declined at the level of from 0 to 5 db. Although his ability was almost recovered during the noon recess, it was more declined at the level of from 5 to 10 dB by the work in the afternoon. The loss level depended upon the frequency band of hearing sound. Although the hearing loss was little at low frequency band, it took longer period of time to recover. On the other hand, the hearing loss was high at high frequency band, but his hearing ability was fully recovered by the next morning (a shorter period of time).

The result shows the level of the recovery during the noon recess from the hearing loss to the speaking band was only half of the beginning level. The hearing loss of the operator's right ear was larger than his left ear. It is presumed that his right ear was closer to the machine than his left ear as he operated the the chain saw. After two years, the chain saw operator had a permanent hearing loss of about 3dB.

# A COMPUTERRIZED METHOD OF MEASURING ENERGY EXPENDITURE IN THE FOREST WORK: PRUNING AND WEEDING

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FDC: 236.1: 245.11/.14: 302--015.5

In XIIXth IUFRO World Congress, we reported that titled by "A Computerized method of Measuring Ergonomic data in the Forest work" in poster session. After that, we improved that method by using the expired gas analizer.

We estimated the physiological load from heart rate by using H.R.Memory during forest work. First, we checked the relationships between heart rate and $O_2$ uptake and energy expenditure simultanueuoly applying step test on each forest worker, and next we calculated the physiological load during work in the energy expenditure (kcal/kg/h) and Relative Metabolic Rate (RMR) using these relationships.

In 1987, we studied the operational efficiency and physiological load of 3 forest workers during work with pruning machines were measured with portable heart rate recorders continuously under 3 levels of work load (i.e. 1 machine per 1 person, 3 machines per 2 persons and 2 machines per 1 person). They prunned 352 trees of SUGI(Japanese cedar) for 3 days at Kyoto University Forest in Wakayama. The work intensities observed during 1 machine per 1 person, 3 machines per 2 persons and 2 machines per 1 person, were 44.2 and 62.3 % of $VO_2$ max, respectively. Energy expenditures of those were 5.09 and 7.36 kcal/kg/h, and those of RMR were 4.0 and 6.2.

In 1988, we studied the operational efficiency and physiological load of another 2 forest workers during weeding by using 2 different tools (sickle and brush cutter) in 3 different sites (i.e. inclination angle are 0, 30 and 40 degree). 2 workers weeded about 7000 square meter of plantted forest for 4 days at Kyoto University Forest in Asyu. We estimated the physiological load by using same method as mentioned above. In the case of using sickle, the work intensities were 46.2 and 50.7 % of $VO_2$ max. Energy expenditures of those workers were 6.98 and 8.67 kcal/kg/h, and those of RMR were 3.9 and 6.5.

In the case of using brush cutter, the work intesities were 44.2 and 55.5 % of $VO_2$ max. Energy metabolisms of those worker were 6.67 and 9.48 kcal/kg/h, and those of RMR were 5.6 and 7.2.

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# THE WORKING POSTURE DURING FELLING, DELIMBING AND BUCKING OPERATION WITH A CHAIN SAW

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FDC: 362.7: 302

In Japan, chain saw is usually used in felling, delimbing and bucking operation. A forest worker operates a chain saw in various working postures during the operation. Besides the weight of a chain saw, these postures seem to be the important factor which cause localized muscular fatigues and/or musculoskeletal disorders, e.g., low back pain. In this paper, the effect of the working posture on the work load was investigated.

Three subjects simulated working postures at floor, waist and shoulder heights when holding a chain saw. Discomfortable body-part, overall discomfort and heart rate were measured. Percentage of maximal muscular strength and moment about low back were calculated.

At shoulder height subjects elevated the arms. At floor height they either bent the trunk or squatted. The left upper limb was a discomfortable body-part at any posture. The low back and the lower limbs were also discomfortable body-parts at trunk-bent posture. Overall discomfort, heart rate and percentage of maximal muscular strength were much higher at arms-elevated posture than at the others when holding a chain saw which weighed more than 6.0 kgf. Moment about low back was much higher at trunk-bent posture than at the others even if a chain saw was not held. In conclusion, it was clear that both arms-elevated posture and trunk-bent posture were stressful.

From the results described above, the optimal working position in felling, delimbing and bucking operation with a chain saw was discussed.

# SOME INVESTIGATIONS ON THE HELICOPTER TYPE LOGGING SYSTEM IN JAPAN

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## SUMMARY

FDC: 31: 376: (52)

Investigations and review have been made on the helicopter type logging system as applied to Japanese national and private forests in recent years, with the purpose of putting together fundamental data needed to systematize practically the helicopter type logging techniques. The result of study shows that there is a marked difference between national forest and private forest in terms of the purpose, the forest type and tree species, the operation period, the operation type, productivity, operational economies of the helicopter yarding operation. For the future, I find it necessary to standardize the helicopter yarding operation as well as to systematize the helicopter type logging techniques on the basis of the fundamental data thus collected.

Keywords: Helicopter yarding, Logging system, Operational condition, Productivity, Economies

# TRENDS OF TROPICAL WOOD CONSUMPTION IN BULGARIA

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## SUMMARY

FDC: 721.1: (497.2)

A tropical wood material consumption analysis has been made since the year 1963 in Bulgaria. It is found that there is a correlation between the consumption of tropical logs and some main components of development: buildings (housing construction); development and adoption of innovation and new technology in the furniture industry; and the price of tropical logs.

On that basis a statistical model is proposed to forecast the consumption of tropical wood material under difference scenarios. Three scenarios are worked out with the model. The results are compared to experts' estimations.

# MACHINE APPLICATION OF CUT STUMP TREATMENT HERBICIDES

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FDC: 232.214: 331.1

The use of mobile whole-tree chippers to convert previously unmerchantable timber into pulp chips and fuel is of importance to forestry managers and to the forest products industries. To the landowner, whole tree harvesting reduces site preparation costs for reforestation by leaving the site clean and relatively undisturbed and may provide a market for unmerchantable timber. Use of whole tree chips for pulp continues to represent an important source of that fiber, particularly with the development of bark separators on chippers.

Although whole tree harvesting offers several advantages to forestry managers and to the forest products industry, a regeneration problem on those mixed hardwood sites invariably occurs. Competition from stump sprouting on those sites is more of a forest regeneration problem than on intensively prepared sites. The current regeneration pracitice on whole-tree harvesting sites employed locally is to allow the site to lay idle one growing season for hardwood sprouts to develop. A foliar herbicide is then applied to "brown-out" the growth followed by a control burn to get a complete kill of the pine competing vegetation. Pine seedlings are then out-planted the following winter. The herbicide cost and delay in planting results in considerable expense at the onset of the regeneration cycle. This paper describes an alternate practice which may reduce regeneration costs and delays and increase pine productivity.

A method for selectively applying cut stump treatment herbicides to the stump of undesirable hardwoods for stump sprout control combined with the operation of tree-to-tree type feller-buncher tree harvester was tested during the summer of 1985. The herbicide application system consisted of a low cost pump-nozzle sprayer attachment installed on a feller-buncher shear head. Fifteen 0.08 hectare test plots located in north central Louisiana stocked predominantly with mixed hardwoods were treated with cut stump treatment herbicides with the harvester-sprayer system. Three replicates of 5 treatments made up the 15 plots for analysis as a radomized complete block experimental design. The five treatments consisted of a control (no herbicide applied), picloram, triclopyr (ester base), triclopyr (amine base), and dicamba--all labeled for cut stump treatment. Hardwood stump sprouting in the feller-buncher treated plots was as low as 5% while sprouting was as high as 67% in the untreated plots--after two growing seasons. After four years growth of 1-0 out-planted loblolly pine, mean pine height was as high as 2.54 m in treated plots and only 2.24 m in the untreated plots. Ground line diameter in treated plots was as high as 5.36 cm and only 3.81 cm in untreated plots. Both height and diameter of the pine trees were significantly greater in the machine applied cut stump treatment herbicide plots than in the untreated plots. The benefits offered by this system may give added incentive to forest landowners to practice reforestation during times of marginal forestry profits.

# PLANNING FOREST OPERATIONS VIA PC-BASED PHOTOGRAMMETRY

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## ABSTRACT

FDC: 311: 587

An innovative desk-top mapping system enables forestry field offices to plan and control forest operations via PC-based photogrammetry. The Scandinavian designed system integrates well-established principles of analytical photogrammetry with various digital mapping programs, e.g. CAD and GIS. This paper demonstrates the flexibility of the system by citing practical applications: For primary data, we use both traditional large-format photography and new small-format aerial survey methods. For spatial analysis and issuing maps, we use a forestry-oriented GIS, TERRASOFT. The examples show (i) that the system is ideally suited for planning and controlling forest operations; (ii) the affordable system meets forestry field office requirements; and (iii) three-dimensional data can be efficiently captured by those with limited training in photogrammetry.

# WORK ORGANIZATION WITH SPECIAL RESPECT TO NOISE ABATEMENT IN SAWMILLS

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FDC: 30: 832.1

After a period of mechanization and automation in timber processing operations of secondary conversion the efficiency of employees should not be impaired furthermore by the working conditions, especially in sawmills. Unhealthy environmental influences have to be reduced by operational techniques and proper work layout.

Work environment requirements - inside and outside the plants - have grown substantially, they are becoming still more important and play - together with safety regulations - an increasing role in wood-using workshops and plants.

With sophisticated mechanized systems industrial plants are engaged to decrease noise, protect hearing capacity and provide medical care, which can be accomplished by machine arrangement, constructional means and work organization.

Methods of investigating the noise situation in sawmills and the exposition of workers at their operating desks to the sources of noise are shown up. It is demonstrated how machine groups fitted together result in a suitable process line, controlled and steered from strictly separated operating cabins with desks and screens, when processing round timber in a high speed production.

# STREAMWATER QUALITY FOLLOWING SELECTIVE LOGGING IN A HUMID TROPICAL FOREST, PENINSULAR MALAYSIA

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FDC: 31: 116.91: (213): (595)

Over the last two decades more than 1.3 million ha. of forest in Peninsular Malaysia has been systematically cleared and converted to agricultural land. Consequently, timber resources nowadays are largely confined to upper watershed area which is highly delicate to disturbance. Associated activities with commercial logging often accelerate soil erosion and sediment transport, and hence, lead to water quality deterioration downstream.

The impact of logging on streamwater quality in a humid tropical forest site of Peninsular Malaysia were investigated using paired watersheds approach. This involved three small watersheds, namely C1, C2 and C3. After three years of calibration period C1 and C3 were logged by "Unsupervised" and "Supervised" logging methods respectively, whereas C2 was left undisturbed as control. For the unsupervised logging method (C1) the operations were left to the discretion of the logger but the cutting regime were restricted to 60 cm dbh for dipterocarp and 45 cm dbh for nondipterocarp. As for the supervised logging method several control measures were imposed. These include higher cutting regimes, proper alignment, construction and maintenance of logging road and having a 20 m buffer strip at both side of streambank.

During the first year after logging suspended solids and turbidity levels in the unsupervised watershed increased by five and six folds, respectively compared to prelogging values. In the second year after logging the levels were still higher by three folds for suspended solids and two folds for turbidity. Significant increases were also observed for K, Ca and Mg concentrations in the unsupervised watershed. However, the increase in $NO_3$ concentration was small and not significantly detected. For the supervised watershed, none of the streamwater parameters was significantly affected following logging operation.

The results strongly suggest that the impact of logging on streamwater quality can be substantially reduced if proper logging guidelines were followed.

# Poster Abstracts
# Résumés d'affiches
# Kurzreferate füt Postersitzungen
# Descripción resumida de posters

Poster abstracts have been arranged in alphabetical order of authors' names.
Les résumés d'affiches ont été disposés par ordre alphabétique des noms d'auteurs.
Die Kurzreferate für Postersitzungen sind in alphabetischer Reihenfolge der Autoren aufgeführt.
Descripción resumida de posters dispuestos por orden alfabético de los nombres de los autores.

### 301 USE OF NIGHT-BREAK PHOTOPERIODIC LIGHTING TO CONTROL SHOOT GROWTH OF CONIFEROUS TREE SPECIES.

Arnott, J.T., (Pacific Forestry Centre, Forestry Canada, Victoria, British Columbia V8Z 1M5, Canada).

The literature indicates that a brief exposure of low intensity light for 1 to 2 h in the middle of the dark period (night-break) delays the onset of dormancy in conifer seedlings. However, night-breaks are not always consistently superior to the more conventional daylength extension treatment for some conifers. Several experiments were conducted from 1986 to 1989 to determine if night-break lighting from a high pressure sodium (HPS) light source could be successfully applied to control shoot growth of *Picea glauca*, *P. engelmannii*, *Psuedotsuga menziesii* var. *glauca* and *Tsuga mertensiana* when grown in container seedling nurseries in southern British Columbia. In all experiments, night-break photoperiodic lighting delayed terminal bud formation in all tree species and promoted seedling growth when compared to controls. Some species responded to the treatment with significant increases in numbers of stem units, while others had significantly longer stem unit lengths. For container seedling nurseries that use HPS lighting for daylength extension to promote seedling growth from after seeding to mid-summer, the 2-h night-break with the an HPS light source would reduce electrical consumption and lamp depreciation by as much as 60 per cent and still provide the same effective control over seedling shoot growth.

### 302 ALTERNATIVE TIMBER HARVESTING PRACTICES FOR TROPICAL FORESTS

Cordero, W., and Howard, A.F. (Associate and assistant professor, Instituto Tecnologico de Costa Rica, Cartago, Costa Rica; and The University of British Columbia, Vancouver, B.C. Canada).

Tropical forests are not being used or managed in a sustainable way and they are vanishing, mostly due to the clearing of forests for cattle raising and agriculture. The application of good silvicultural treatments in the tropics, is limited by the excessive damage caused by current logging practices. By improving and/or developing alternative harvesting systems, a wider variety of silvicultural treatments would be possible which could lead to successful management of natural tropical forest. Harvesting operations can be more efficient and besides reducing the environmental cost, employment opportunities in the forestry sector can be created. This research project investigates alternative harvesting systems for natural tropical stands. Four harvesting systems based on machinery and oxen are evaluated, and compared based on: ground and residual stand condition after logging, total harvesting costs per $m^3$, labor and capital requirements, and logging productivity of the system.

## 303 ADJUSTMENT OF PERFORMANCE DEGREE DIFFERENCES IN MECHANIZED FOREST OPERATIONS

Gjedtjernet, A.M. Furuberg. Norwegian Forest Research Institute (NISK), Norway.

Performance rating is a complicated component of forest work studies. Subjective performance rating and different methods for adjustment of the performance in relation to standard times is described in the literature. However, in the study of mechanized methods where performance degree differences are both machine and person dependant, such methods are in most cases not suitable. In regional work studies some research workers may operate under one condition while other workers operate under other working conditions. In this case the workers performance rate may influence the time consumption which lead to a miscalculation of the variation of time consumptions with the working conditions. In a production study of 35 tractor operators with different equipment in varying forest terrain, performance degree differences were measured with the use of standard roads (constant working conditions). The relative degree of performance was used to adjust production. It was possible to evaluate this method during the analysis of one of the study's suboperations. The deviation between the adjusted and the nonadjusted time consumption functions is considerable. The nonadjusted model also produces illogical results. The study places emphasis on the importance of developing feasible methods for performance degree adjustments in studies involving more than one forest worker. (NISK research project no. 6.9.1.5.)

## 304 THE NATURE AND SETTING OF OPERATIONS RELATING TO COMMUNITY FORESTRY

Griffin D.L., Gilmour D.A., Fisher R.J., Ingles A., Jackson M., Malla Y.B., Shepherd K.R. (Nepal-Australia Forestry project, c/o Dept of Forestry, Australian National University, Canberra, Australia AND Maharjan M.R., Bhattarai K., Dept of Forests, HMG Nepal, Kathmandu, Nepal.)

Increasingly forestry operations need to respect a variety of constraints of a social nature. This is especially so in regard to community forestry in developing countries where the relevant technology must be seen inthe wider perspective afforded by the social, economic and ecological contect. Operations must be appropriate to the social structures of the actual or potential user groups, the varied needs for specific forest products, the seasonal nature of product demand and the availability of voluntary labour, and the appropriateness of institutional arrangements. Unnecessary technological introductions and innovations should be avoided: often traditional tools can be adapted.

In community forestry there is a necessity for users to feel in adequate control of the resource and its utilization yet the wider interests in the proper management of the resource must also be recognized. A careful and delicate balance must, therefore, be struck in establishing arrangements for the management of operations and utilization. If these are too technical they will not be understood by users, which two consequent results: the arrangements will be ignored and/or too much power and responsibility will drift to the technically competent representatives of the national interest. The chances of creating viable arrangements suited to modern needs may well be better if the arrangements build upon existing indigenous systems where these are present. These topics will be illustrated by reference to experience in Nepal at the Nepal-Australia Forestry Project.

## 305 PHYSIQUE AND PHYSICAL ABILITY OF JAPANESE FORESTRY WORKERS.

Imatomi, Y. (Forestry and Forest Products Research Institute, Ministry of Agriculture, Forestry and Fisheries, Ibaraki, Japan.)

According to census in 1985, the number of Japanese forestry workers is about 140,000. The rate of workers under 50 years old is 40.5%, that of workers over 50 years old is 59.5%. As this fact shows, the rate of middle and old aged forestry workers has increased in Japan recently, and hence studies on work intensity, safe working method and so on, suitable for them in forest operations have been necessary. Then the author examined physique and physical ability of 97 male forestry workers employed in forest owner's associations to make clear the characteristic of their physique and the change of physical ability as one grows old.

The results of this examination are as follows. (1) On physique, they are lean, and their physique is classified into the endomorphic mesomorph type according to the Heath-Carter Somatotype Method(J.E.Lindsay Carter). (2) On physical ablity, they are stronger in muscular strength than common people, but they are rather inferior to common people in agility and balance. And each physical ability declines as one grows older, the workers over 50 years old decline particularly in standing trunk flexion. The results from this examination accordingly show that middle and old aged forestry workers need special care to train their agility, flexibility and balance.

## 306 THE OPERATING ENVIRONMENT OF THE FINNISH FOREST MACHINE CONTRACTOR.

Juntunen, M-L., Kanninen, K., and Mäkinen, P. (The Finnish Forest Research Institute, Helsinki)

Finland has 2,500 independent forest machine contractors who perform the major part of off-road timber haulage - about 40 million $m^3$ annually. In addition, an increasing proportion of timber preparation - over 10 million $m^3$ per year - is carried out by contractors with multi-function machines. In Finland contractors are independent entrepreneurs, although work site organization and work supervision are the responsibility of the timber company. In 1986, a total of 74 forest contractors were interviewed by the Finnish Forest Research Institute. The average age of contractors was 40 and they had been in the field for an average of 13 years. Most contractors owned one or two forest machines and the average age of machines was six years. The majority were one-owner companies. Fourteen contractors were also involved in farming. Typical to the employment were seasonal variation and long working days. Contractors were quite satisfied with the work site organization made by timber companies, although the profitability of contract work during 1983 to 1985 was only poor or fair. Forest machine contractors exhibited fairly few psychological symptoms. The reason for the scarcity of symptoms is most likely the good balance between the contractors' professional and personal profiles. The physical ailments of the contractors seem to center in the neck and shoulders, as well as the lumbar region. It seems that, the machine environment, the character and the organization of work may cause physical problems for the contractors.

## 307 ADDING MECHANICAL HARVESTING TECHNIQUES TO CABLE YARDING OPERATIONS

Kellogg, Loren, Assistant Professor, Oregon State University

Cable logging is the prevalent yarding method in the mountainous terrain of the Pacific Northwest. In the past, with a steady source of valuable old-growth timber, there were little incentives for changing the basic systems and equipment. However now there is a gradual but steady transition from large old-growth timber to much smaller second-growth trees and there are relatively high labor rates in the region. Thus the opportunities and interest to add mechanical harvesting techniques to cable operations is increasing.

The first area of change has been at the landing. Instead of manually felling and processing trees prior to log length yarding, some operations are adding a mechanical processing machine at the landing to work alongside the yarder. Most of the felling is still completed manually because of the steep terrain. Utilization of the mechanical processing machine and the logging system output varies greatly. It is related to the yarding production rate, the size and design of the landing, and design characteristics of the processing machine. A second area of change is replacing manual felling with mechanical felling and bunching by using a self-levelling machine that is capable of operating on some steep slopes in the Pacific Northwest. Mechanized felling and bunching improves utilization of the delimber and enhances cable yarding production. A third area of change is with more efficient hooking and unhooking techniques such as radio controlled chokers or grapple carriages. The future of mechanized harvesting in the Pacific Northwest will be affected by answers to critical issues regarding new equipment and system performance in terms of economics, utilization, logging impacts on site productivity, worker safety and training.

## 308 EFFECTS OF DIFFERENT OVERWINTER STORAGE REGIMES ON SHOOT GROWTH AND NET PHOTOSYNTHETIC CAPACITY IN *Pinus sylvestris* seedlings

Mattsson, A. and Troeng, E. (Department of Forest Yield Research, Sweedish University of Agricultural Sciences, S-770 73 Garpenberg, Sweden and Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, S-750 07 Uppsala, Sweden).

Seedlings of *Pinus sylvestris* were cold-stored for three or six months at -4°C or 2°C or overwintered outdoors. Dry weight development and net photosynthetic capacity were then measured during a 60-day cultivation period in a controlled environment. In addition, net photosynthetic performance was followed continously in the field during the first month after outplanting.

In all storage regimes the longer storage period gave a faster growth initiation. Photosynthetic recovery was faster for seedlings stored at 2°C than at -4°C, due to better recovery of stomatal conductance. This was found both in the laboratory and under field conditions. The results suggest that there is little difference in seedling development between storage temperatures of -4°C and 2°C whereas outdoor storage might cause certain negative effects on subsequent growth of seedlings. This result is discussed with regard to the present winter climate. Key words: Pinus sylvestris, seedlings, cold storage, outdoor storage, biomass development, net photosynthesis.

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## METHODS AND RESULTS FROM FOUR YEARS OF STUDIES OF BASIC HANDLING CHARACTERISTICS OF WOOD FUELS

Mattsson, J. (Department of Operational Efficiency, Swedish University of Agricultural Sciences, Garpenberg, Sweden)

Operational problems in heating plants using wood fuels are usually related to problems with internal transport and the handling of the fuel. More knowledge is needed of the handling characteristics of wood fuels. Basic handling characteristics were measured for sawdust, fuel pellets, fuel chips, hogged fuel and chunkwood. The aim was to find relations between basic handling characteristics and easily measured fuel properties, and to establish data as guidelines for the design of feeding systems in heating plants. The angle of repose was 25 - 55° and increased with the increasing ratio of particle length to thickness and with increasing content of hooked or long particles. The angle of static friction, 10 - 40°, was affected more by the kind of surface than the type of fuel and followed the order (lowest first): coated plywood, urethane rubber, particle board, stainless steel, concrete and rubber belt conveyor. The tendency to bridge over outlet openings varied considerably and increased with a greater content of hooked or long particles, a deeper fuel bed over the opening and a higher moisture content. The results indicate that more attention should be paid to the particle shape and content of particles known to cause problems.

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## STUMP PLANTING IN AGROFORESTRY IN HAITI

Reid, R.K., Nursery Specialist, Haiti Agroforestry Research Project, SECID/Auburn University, and Welle, P.W., Project Coordinator, CARE International, Port-au-Prince, Haiti.

A stump is a special type of cutting which consists of a short, pruned stem and a strong, pruned taproot. Since 1987, the Agroforestry Outreach Program in Haiti has been producing stumps as an alternative to containerized planting stock. Stumps are a valuable part of this extension program because they can be produced in on-farm nurseries without using scarce irrigation water or chemical fertilizer. Stumps of *Cassia siamea* Lam. and *Azidirachta indica* A. Juss. produced in this type of nursery have been compared to traditional containerized planting stock in field tests in Haiti. *Cassia siamea* stumps had a survival rate of 68% and were 105 cm tall after six months, while *A. indica* stumps had a 49% survival rate and were 97 cm tall for the same period. Stumps did not perform as well as seedlings produced in small plastic sacks. Stump survival was not as good as survival of seedlings from rigid-wall, commercially-available containers. However, surviving stumps grew as well as these seedlings grew, especially in trials on a good site.

### 311 AN ARTICULATED TRACKED VEHICLE FOR FORESTRY APPLICATIONS

Sasaki, S., and Yamada, T. (Forestry and Forest Products Research Institute, Tsukuba, Japan)

Japan consists of four main islands extends from north to south and about seventy percent of the area is covered by many varieties of tree species of softwood and hardwood. However, harvesting is presently limited because of problems associated with the lack of technically sound and economically efficient logging equipment and systems for use under the adverse harvesting conditions encountered in Japan. Some characteristics that contribute to adverse harvesting conditions are steep slopes, fragile soils, scattered low-volume stands, and rugged terrain. The articulated tracked vehicle was developed to solve some of the harvesting problems. We explain design concepts, unique features, and specifications of the vehicle. The principle features of the vehicle include: (1) a joint has four degrees of freedom with hydraulic cylinders; (2) hydrostatic transmission system with two variable displacement pumps and four fixed displacement sprocket motors; and (3) an unique design of a differential gear and independent drive between left and right track. A mathematical model was developed to examine the effect of the active pitch control for traveling on steep slopes; field trials of the vehicle were also conducted to check our mathematical model. Results will be also presented at this poster session.

### 312 EFFECTS OF RUGGED TERRAIN ON THE COST OF FOREST ROAD CONSTRUCTION IN JAPAN

Sawaguchi, I. (Forestry and Forest Products Research Institute, Ibaraki, Japan).

Factors such as steep slopes, fragile soils, and rugged terrain contribute to the high cost of forest road construction in Japan. An average cost of forest road construction is approximately $400 per meter or $640,000 per mile. Therefore, persons in the forestry industry, including contractor, harvesting engineers, and road planners, should clearly understand the effects which various factors have on the cost of forest road construction. Quantification Theory Type I was used for analyzing relationships among the factors. Information used for this statistical analysis were road specifications, plans and terrain maps of 79 routes. The results may be summarized as follows: (1) the factors which significantly effect on the cost of forest road construction were slope of ground around forest road, the grade of the forest road, types of soils, and length of construction section. Multiple correlation coefficient for the estimated cost was 0.87 and partial correlation coefficient for slope and grade was 0.63 and 0.64, respectively; and (2) the selection of construction method also significantly affects on the construction cost. The paper explains the principle of Quantification Theory I and reports how the technique was used for analyzing various factors which effect on the cost of forest road construction.

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### MEASUREMENT SYSTEM OF NOISE AND VIBRATION OF CHAINSAW IN JAPAN

Suzuki, T. (Forestry and Forest Products Research Institute, Tsukuba, Japan)

In 1974 a measuring system for testing noise and vibration of portable forestry machines was developed by the Forestry and Forest Products Research Institute in Tsukuba. Since legally authorized by the Ministry of Labor in 1977 as th Japanese official measuring system, it has been applied to test noise and vibration of portable forestry machines used in Japan by the Forestry Machinery Association. The paper explains the principle of the vibration and the sound measuring system. The vibration measuring system consists of a small transducer fixed on the handle grip with steel band. The pressure is set over $10kg/cm^2$. The piezo electric type transducer is sensible to three direction of accelerations in a moment. Its weight is under 50g. Three real time frequency analyzer is the heart of this device which has 1/3 octave bands. Engine speed is set in every one-thousand rotations per minute (rpm). The sound measuring system is similar to one of vibration. A condenser microphone, small transducer, is fixed beside the operator's right ear. The measurement of frequency ranges from 100 to 10,000 Hz. This paper also report the results from our study to measure the noise and vibration of chainsaws for last ten years (about 500 chainsaws). The logs used for a test were selected based on such factors as species, moisture content, size, and hardness. Cutting was done with bucking style.

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### HELICOPTER LOGGING IN JAPANESE PRIVATE FORESTS - OPERATIONS AND A MODEL OF REGIONAL UTILIZING SYSTEM

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In this decade, some of japanese private forest managers have become to utilize helicopters as a logging method more frequently than ever. They apply it especially for thinning operations. This tendency is most conspicuous in Yoshino district, which is famous for most developed forestry technique and artificial stands of highest quality in Japan. Cost of the logging operations is rather high. But for some reasons they choose this method, instead of other orthodox methods, for example, cable systems. The reasons are :1) it is suitable for operations of rather small lots, 2)it requires few workers when logging operations are performed, 3) damage of residual stands and transported logs could be minimum. This situation is connected with recent crucial social circumstance of japanese forestry - decreasing forest workers, low price of logs, etc. The results of our investigation of helicopter logging operation in Yoshino district are as follows. Almost all operations are for thinning of artificial forests. Operations are performed by 1,000 kg class helicopters rented by aero-companies by the time. Cost of a whole operation is almost proportional to cycle time and we can estimate cycle time in relation to parameters of distance and elevating height of flight path and length of sling. Average cycle time is about 3 minutes. Average logging distance is about 1.5 km. With the results of analyzing operational efficiency and information of operational, stand and terrain conditions, we try to construct a model of regional utilizing system. In this model, we decide arrangement and location of heliports adequately in relation to those conditions and present road network.

## 315 THINNING-HARVESTING OPERATIONS OF WHEEL-TYPE SKIDDER AND DAMAGE OF RESIDUAL STANDS AND FOREST FLOOR AFTER THE OPERATIONS.

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We investigated thinning-harvesting operations in Japanese National Forest. The operations were performed at stands in Chugoku region, middle east of Japan. This report is a case study of them.

Terrain is rather easy, with average ground slope of about 14 degree. The stands is of 60 year old Japanese cypress, with average DBH of 20 cm or so. After the operations, natural regeneration is planned to be applied to the stands.

Thinning rate is about 40 %. A 4 men crew performs the operations by a wheel-type skidder. It hauls tree-length logs downhill to strip roads using its rear-mounted winch and skids them to landings. In order to enhance operational efficiency and to prevent damage of residual stands and forest floor, they fell trees to form a shape of a fish-bone, with tree tops down, and haul them along the center line of the shape.

Applying this method with "fish-bone shaped hauling path" went well. We observed average operational efficiency of 0.9-1.0 m3/man*hour. The damage of the residual stands was as follows. 1) 20% of more or less damaged trees in number/area, and 2) 30% of destroyed young growths in number/area. In case that the skidder ran on forest floor directly, soil compaction within the depth of 15 cm was found to be not significantly different to non-compacted part. We analyzed the operations with time-study method and concluded that they should rearrange or enlarge landings to reduce dead-time and enhance operational efficiency.

## 316 OPERATORS' FATIGUE OF YARDER AND TRACTOR IN JAPAN.

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This paper discribes the results of investigation and analysis by "Subjective Symptoms of Fatigue (SSF)" to yarder's and tractor's operators from the point of human engineering. The inquire as to "SSF" consists of 30 items, being classified into 3 categories of each 10 items. "Category-Ⅰ(Ⅰ)" shows the symptoms of "drowsiness and dullness", "Category-Ⅱ(Ⅱ)" "difficulty in concentration", and "Category-Ⅲ(Ⅲ)" "projection of physical disintegration".

The data investigated in this report consists of 217 responses by 48 yarder's operators and 167 responses by 31 tractor's operators. As the results of analysis of "SSF", the level of their work intensity were allowable, the average values of frequencies of symptoms at "after work" being 10.4% on yarder's operators and 11.9% on tractor's operators. The mean complaint frequencies in each category were 12.8% for Ⅰ, 6.3% for Ⅱ, 12.1% for Ⅲ on yarder's operators and 14.0% for Ⅰ, 8.1% for Ⅱ, 13.5% for Ⅲ on tractor's operators. There were much complaints of pain of some parts of the body, the high frequencies of symptoms at "after work" being "Feel strained in the eyes", "Feel stiff in the shoulders", "Feel a pain in the back", "Get tired of the legs" and "Want to lie down". As the item of symptoms of higher complaint frequencies at "before work" being "Feel stiff in the shoulders" and "Feel a pain in the back", it can be said that operators always feel the fatigue at the part of shoulder and waist. Considering the above results, it can be said that the factor causing operators fatigue would be the long term duty in keeping a sitting posture, the wrong arrangement of controls, and the vibration of the yarder and the tractor.

## 317 SHEAR STRENGTH MEASUREMENTS OF FOREST SOILS.

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Sinkage and shear strength in different soils have been measured with a new kind of testing device. The test-rig acts as a slipping rigid wheel simulating the forces acting beneath a wheel of a forestry machine. Three different illuvial naked soils, one peat soil and three forest floors on podzolic moraine soils are tested so far.

The forest soils differ from the sediment soils in many respects. Already low normal loads give a marked sinkage into the humus layer which means quite high rolling resistance. They have also a high shear strength up to a level where the root mat breaks, but then the shear strength could even decrease. The high shear strength of the root mat may give a false believe in a strong soil. When the root mat breaks the moist underlying mineral soil could easily give away resulting in a bog down of the forestry machine.

## 318 THREE DIMENSIONAL MOVEMENT-ANALYSIS OF PLANTING WORK IN JAPAN.

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Because Japanese forest has such characteristics as steep slopes, rugged terrain, and difficult sites, most of the tree planting are done by manual workers. There are many tools and methods used for planting the tree seedlings, depending upon the localities in Japan. We conducted a study to quantify and standardize the physiological load of the manual planting work for the purpose of developing an easier and efficient manual planting method. Reports from our research study include: (1) a time study of physical movement; (2) simulation studies of physical movement on various slopes; (3) instrumentations and procedures used for the study; (4) analysis of the center of physical gravity, the angles of waist, knees, elbows, and shoulders; and (5) analysis of the movements of hands and feet. Based on the analysis of the physical postures and movements, we also report on the physical parts where the strains concentrate, the dangerous postures for manual planting work, the movement of active muscles, and the intensity of manual planting work.